

THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE *EVERYDAY PRACTICAL* **ELECTRONICS**

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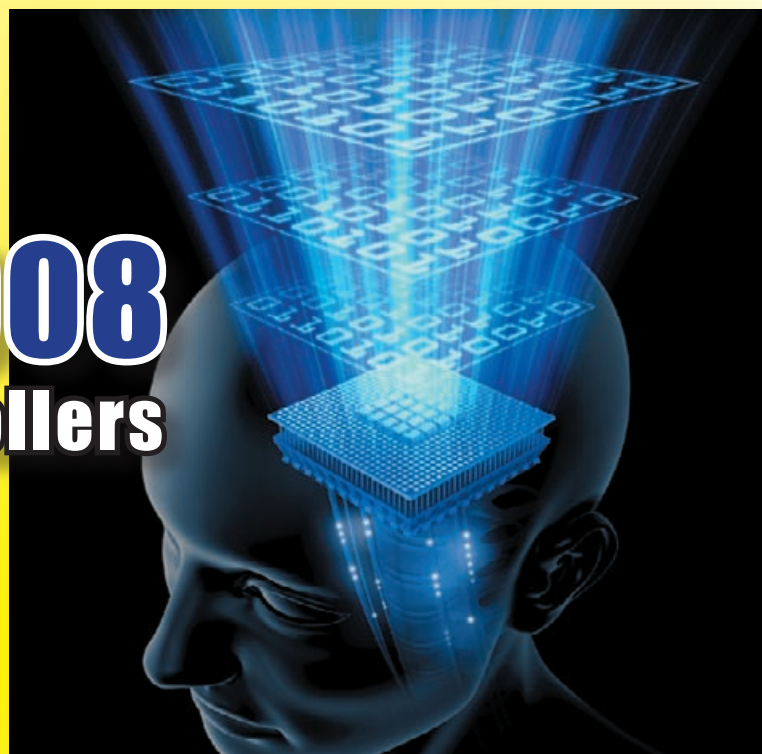
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NEW SERIES

TEACH-IN 2008

Using PIC microcontrollers

Part One – Introduction to
PIC microcontrollers and
the Development Interface
Board construction

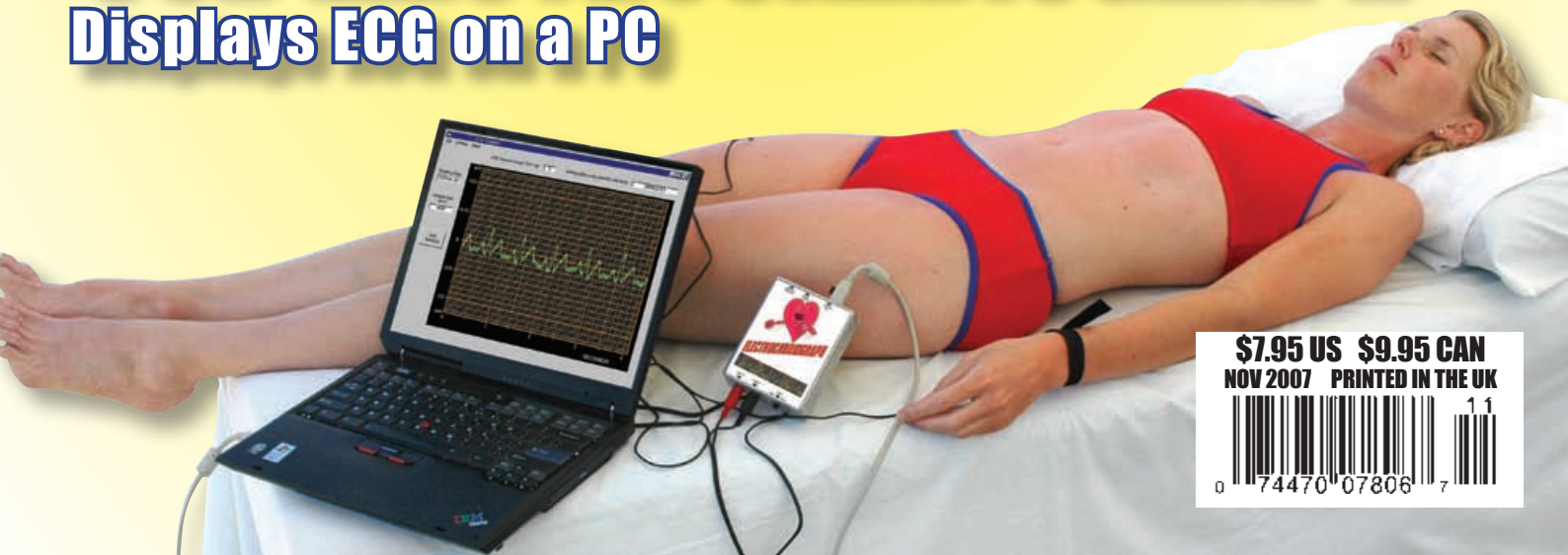


VEHICLE VOLTAGE MONITOR

Monitor voltages and sensor signals in your car

USB ELECTROCARDIOGRAPH

Displays ECG on a PC



\$7.95 US \$9.95 CAN
NOV 2007 PRINTED IN THE UK



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HB7 Stirling Engine

Base measurements: 128 mm x 108 mm x 170 mm, 1 kg
Base plate: beech - Working rpm: 2000 rpm/min. (the engine has a aluminium good cooling Cylinder)
Bearing application: 10 high-class ball-bearings
Material: screw, side parts all stainless steel
Cylinder brass, Rest aluminium and stainless steel.
Available as a kit £80.75 or built £84.99
www.mamodspares.co.uk



HB9 Stirling engine

Base measurements: 156 mm x 108 mm x 130 mm, 0,6 Kg
Base plate: beech Working rpm: approx. 2,000 min
Bearing application: 6 high-class ball-bearings
Material of the engine: brass, aluminium, stainless steel
running time: 30-45 min.
Available as a kit £97.75 or built £101.99
www.mamodspares.co.uk



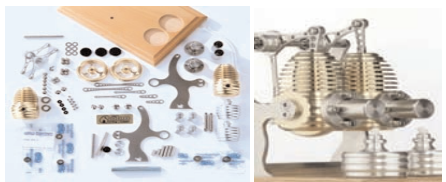
HB10 Stirling Engine

Base measurements: 156 mm x 108 mm x 130 mm, 0,6 Kg
Base plate: beech Working rpm: approx. 2,000 rpm
Bearing application: 6 high-class ball-bearings
Material of the engine: brass, aluminium, stainless steel
running time: 30-45 min
Available as a kit £97.75 or built £101.99
www.mamodspares.co.uk



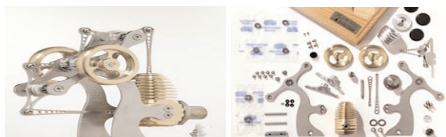
HB11 Stirling Engine

Base measurements: 156 mm x 108 mm x 130 mm, 0,7 Kg
Base plate: beech
Working rpm: 2000 - 2500 rpm/min, run Bearing application: 4 high-class ball-bearings
Material: screw, side parts total stainless steel
Cylinder brass Rest aluminium, stainless steel.
Available as a kit £97.75 or built £101.99
www.mamodspares.co.uk



HB12 Stirling Engine

Base measurements: 156 mm x 108 mm x 130 mm, 1 Kg
Base plate: beech Working rpm: 2000 - 2500 rpm/min, Bearing application: 6 high-class ball-bearings
Material: screw, side parts total stainless steel
Cylinder brass Rest aluminium, stainless steel.
Available as a kit £136 or built £140.25
www.mamodspares.co.uk



HB13 Stirling Engine

Base measurements: 156 mm x 108 mm x 150 mm, 0,75 kg
Base plate: beech Working rpm: 2000 - 2500 rpm/min, Bearing application: 6 high-class ball-bearings
Material: screw, side parts total stainless steel
Cylinder brass Rest aluminium, stainless steel.
Available as a kit £97.75 or built £101.99



STEAM ENGINE KIT

Everything in the kit enables you to build a fully functional model steam engine. The main material is brass and the finished machine demonstrates the principle of oscillation. The boiler, uses solid fuel tablets, and is quite safe. All critical parts (boiler, end caps, safety vent etc.) are ready finished to ensure success. The very detailed instruction booklet (25 pages) makes completion of this project possible in a step by step manner. Among the techniques experienced are silver soldering, folding, drilling, fitting and testing. £29.70 ref STEAMKIT Silver solder/flux pack £3.50 ref SSK

www.mamodspares.co.uk



HB14 Stirling Engine

Base measurements: 156 mm x 108 mm x 150 mm, 1 kg
Base plate: beech Working rpm: 2000 - 2500 rpm/min, . Incl. drive-pulley for external drives Bearing application: 10 high-class ball-bearings
Material: screw, side parts total stainless steel
Cylinder brass Rest aluminium, stainless steel
Available as a kit £140.25 or built £144.50
www.mamodspares.co.uk



HB15 Stirling Engine

Base measurements: 128 mm x 108 mm x 170 mm, 0,75 kg
Base plate: beech Working rpm: 2000 rpm/min. (the engine has a aluminium good cooling Cylinder)
Bearing application: 6 high-class ball-bearings
Material: screw, side parts total stainless steel
Cylinder brass Rest aluminium, stainless steel
Available as a kit £97.75 or built £102
www.mamodspares.co.uk



HB16 Stirling Engine

Base measurements: 128 mm x 108 mm x 170 mm, 1 kg
Base plate: beech Working rpm: 2000 rpm/min. (the engine has a aluminium good cooling Cylinder)
Bearing application: 10 high-class ball-bearings
Material: screw, side parts total stainless steel
Cylinder brass Rest aluminium, stainless steel.
Available as a kit £140.25 or built £144.50



2kW WIND TURBINE KIT

The 2kW wind turbine is supplied as the following kit: turbine generator 48v three taper/ twisted fibreglass blades & hub 8m tower (four x 2m sections) guylines / anchors / tensioners / clamps foundation steel rectifier 2kW inverter heavy-duty pivot tower. £1,499



Solar Panels

We stock a range of solar photovoltaic panels. These are polycrystalline panels made from wafers of silicon laminated between an impact-resistant transparent cover and an EVA rear mounting plate. They are constructed with a lightweight anodised aluminium frame which is predrilled for linking to other frames/roof mounting structure, and contain waterproof electrical terminal box on the rear. 5 watt panel £29 ref 5wnav 20 watt panel £99 ref 20wnav 60 watt panel £249 ref 60wnav. Suitable regulator for up to 60 watt panel £20 ref REGNAV



Solar evacuated tube panels

(20 tube shown) These top-of-the-range solar panel heat collectors are suitable for heating domestic hot water, swimming pools etc - even in the winter! One unit is adequate for an average household (3-4 people), and it is modular, so you can add more if required. A single panel is sufficient for a 200 litre cylinder, but you can fit 2 or more for high water usage, or for heating swimming pools or underfloor heating. Some types of renewable energy are only available in certain locations, however free solar heating is potentially available to almost every house in the UK! Every house should have one - really! And with an overall efficiency of almost 80%, they are much more efficient than electric photovoltaic solar panels (efficiency of 7-15%). Available in 10, 20 and 30 tube versions. 10 tube £199, 20 tube £369, 30 tube £549. Roof mounting kits (10/20 tubes) £12.50, 30 tube mounting kit £15



BENCH PSU 0-15V 0-2a Output
and voltage are both smooth and can be regulated according to work, Input 230V, 21/2-number LCD display for voltage and current, Robust PC-grey housing Size 13x15x21cm, Weight 3,2kg £48 REF trans2



NEW ELECTRONIC CONSTRUCTION KITS

This 30 in 1 electronic kit includes an introduction to electrical and electronic technology. It provides components that can be used to make a variety of experiments including Timers and Burglar Alarms. Requires: 3 x AA batteries. £15.00 ref BET1803

AM/FM Radio This kit enables you to learn about electronics and also put this knowledge into practice so you can see and hear the effects. Includes manual with explanations about the components and the electronic principles. Req's: 3 x AA batts. £13 ref BET1801

This **40 in 1 electronic kit** includes an introduction to electrical and electronic technology. It provides components that can be used in making basic digital logic circuits, then progresses to using Integrated circuits to make and test a variety of digital circuits, including Flip Flops and Counters. Req's: 4 x AA batteries. £17 ref BET1804

The **75 in 1 electronic kit** includes an introduction to electrical and electronic technology. It provides components that can be used to make and test a wide variety of experiments including Water Sensors, Logic Circuits and Oscillators. The kit then progresses to the use of an integrated circuit to produce digital voice and sound recording experiments such as Morning Call and Burglar Alarm. Requires: 3 x AA batteries. £20 ref BET1806
www.slips.co.uk

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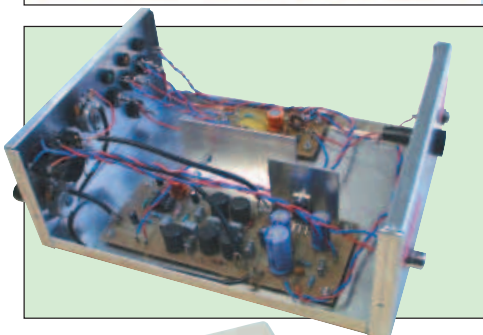
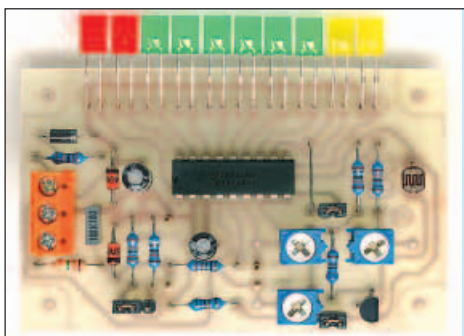
PROJECTS ... THEORY ...
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POPULAR FEATURES ...

VOL. 36. No. 11 NOVEMBER 2007

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Our December 2007 issue will be published on Thursday, 8 November 2007, see page 88 for details.

Projects and Circuits

- VEHICLE MULTI-VOLTAGE MONITOR** by John Clarke 12
Monitors voltages and sensor signals in a car
- USB ELECTROCARDIOGRAPH** by Jim Rowe 34
Displays ECG on a PC
- EXPERIMENTER'S AUDIO SYSTEM** by Stef Niewiadomski 58
Audio preamp, filters, power amp and PSU for radio experiments
- INDUCTANCE & Q-FACTOR METER – 2** by Leonid Lerner 70
A wide range multi-frequency inductance and Q-factor meter

Series and Features

- TECHNO TALK** by Mark Nelson 10
Witricity: Is Tesla's Dream Coming True?
- TEACH-IN 2008 – PART 1** by John Becker 20
Using PIC Microcontrollers – Introduction
- IFA ELECTRONICS SHOW BERLIN** Barry Fox reports 28
- CIRCUIT SURGERY** by Ian Bell 31
Inductor size and SPICE simulation
- PIC N' MIX** by Mike Hibbett 46
Using Flowcharts
- THE POWER OF MECHATRONICS – PART 6** by Colin Greaves 54
A simple approach to RF networking
- PRACTICALLY SPEAKING** by Robert Penfold 66
Static charge vulnerability
- NET WORK** by Alan Winstanley 82
Anti-virus trials and tribulations

Regulars and Services

- EDITORIAL** 7
- NEWS** – Barry Fox highlights technology's leading edge 8
Plus everyday news from the world of electronics
- PLEASE TAKE NOTE** 17
V2 PC Scope
- CD-ROMS FOR ELECTRONICS** 50
A wide range of CD-ROMs for hobbyists, students and engineers
- SUBSCRIBE TO EPE** and save money 68
- PIC RESOURCES CD-ROM** 69
EPE PIC Tutorial V2, plus PIC Toolkit Mk3 and a selections of PIC-related articles
- BACK ISSUES** Did you miss these? 76
- PIC PROJECTS** A plethora of PIC projects on CD-ROM 78
- READOUT** John Becker addresses general points arising 79
- ELECTRONICS MANUALS** 81
The *Modern Electronics Manual* and *Electronics Service Manual* on CD-ROM
- DIRECT BOOK SERVICE** 83
A wide range of technical books available by mail order, plus more CD-ROMs
- EPE PCB SERVICE** 86
PCBs for EPE projects
- ADVERTISERS INDEX** 88

Readers' Services • Editorial and Advertisement Departments 7

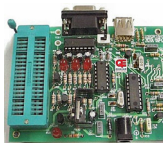
PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:

40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU010) £18.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

NEW! USB & Serial Port PIC Programmer



USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.

Kit Order Code: 3149KT - **£39.95**

Assembled Order Code: AS3149 - **£49.95**

NEW! USB 'All-Flash' PIC Programmer

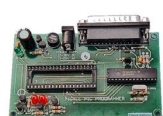
USB PIC programmer for all 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows XP Software. ZIF Socket and USB lead not incl.



Assembled Order Code: AS3128 - **£44.95**

Assembled with ZIF socket Order Code: AS3128ZIF - **£59.95**

'PICALL' ISP PIC Programmer



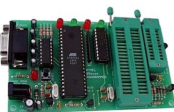
Will program virtually all 8 to 40 pin serial-mode AND parallel-mode (PIC15C family) PIC microcontrollers. Free Windows software.

Blank chip auto detect for super fast bulk programming. Optional ZIF socket.

Assembled Order Code: AS3117 - **£24.95**

Assembled with ZIF socket Order Code: AS3117ZIF - **£39.95**

ATMEL 89xxxx Programmer



Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.

Kit Order Code: 3123KT - **£24.95**

Assembled Order Code: AS3123 - **£34.95**

Introduction to PIC Programming

Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1 rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.



Kit Order Code: 3081KT - **£16.95**

Assembled Order Code: AS3081 - **£24.95**

ABC Maxi AVR Development Board

The ABC Maxi is ideal for developing new designs. Open architecture built around an ATMEL AVR AT90S8535 microcontroller. All circuits are embedded within the package and additional add-on expansion modules are available to assist you with project development.



Features

8 Kb of In-System Programmable Flash (1000 write/erase cycles) • 512 bytes internal SRAM • 512 bytes EEPROM • 8 analogue inputs (range 0-5V) • 4 Opto-isolated Inputs (I/Os are bi-directional with internal pull-up resistors) • Output buffers can sink 20mA current (direct LED drive) • 4 x 12A open drain MOSFET outputs • RS485 network connector • 2-16 LCD Connector • 3.5mm Speaker Phone Jack • Supply: 9-12Vdc

The ABC Maxi STARTER PACK includes one assembled Maxi Board, parallel and serial cables, and Windows software CD-ROM featuring an Assembler, BASIC compiler and in-system programmer.

Order Code ABCMAXISP - **£89.95**

The ABC Maxi boards only can also be purchased separately at £69.95 each.

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU445 £8.95

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output.

Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two & Ten Channel versions also available. Kit Order Code: 3180KT - **£44.95**

Assembled Order Code: AS3180 - **£54.95**



Computer Temperature Data Logger



Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.

Kit Order Code: 3145KT - **£17.95**

Assembled Order Code: AS3145 - **£24.95**

Additional DS1820 Sensors - **£3.95 each**

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.

Kit Order Code: 3140KT - **£54.95**

Assembled Order Code: AS3140 - **£69.95**



8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.

Kit Order Code: 3108KT - **£54.95**

Assembled Order Code: AS3108 - **£64.95**



Infrared RC 12-Channel Relay Board



Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm.

Supply: 12Vdc/0.5A

Kit Order Code: 3142KT - **£47.95**

Assembled Order Code: AS3142 - **£59.95**

Audio DTMF Decoder and Display



Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic or direct from the phone line. Characters are displayed on a

16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU445). Main PCB: 55x95mm.

Kit Order Code: 3153KT - **£24.95**

Assembled Order Code: AS3153 - **£34.95**

Telephone Call Logger

Stores over 2,500 x 11 digit DTMF numbers with time and date. Records all buttons pressed during a call. No need for any connection to computer during operation but logged data can be downloaded into a PC via a serial port and saved to disk. Includes a plastic case 130x100x30mm. Supply: 9-12V DC (Order Code PSU445).

Kit Order Code: 3164KT - **£54.95**

Assembled Order Code: AS3164 - **£69.95**



Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

Embedded Engineer's Development Tool (Atmel 89S & AVR)

At last the development tool kit for Atmel 89S & AVR devices that engineers have dreamed of has arrived. The kit includes a Built-in ISP Programmer, Target Section, Interfacing Board, Cables, eBook with codes, e-Learning Software with explanation and CD all in one neat package. Devices covered include 89S51, 89S52, 89S8253, mega8515, mega8535, mega8, mega16 & mega32.

Features

Designed for working professionals, students and product development companies. You can connect any device like LCD, 7-Segment, Sensors, Switches to any desired port of the microcontroller. No dedicated connections between microcontroller and the interfacing sections. You can connect anything, anywhere. e-Learning Tutorial and Book are included. Once you start using the kit, you will should never feel the need to attend any trainings because it is simple to use and all concepts are explained in simple language using the tutorial and book. Includes 89S51, 89S52, ATmega8, ATmega16, ATmega32 In-circuit Programmer - no need to buy a separate programmer! No ZIF Sockets. No hassle inserting and removing microcontroller to program. In-circuit programming reduces development time as you do not need to move microcontroller.

Contents

- In circuit programmer for 89S and AVR series (supports up to Atmega128)
- 89S51/52 target section
- ATmega8 Target section
- ATmega16/32 Target section
- Switches
- Relays
- LEDs
- 7 Segment Displays
- 16 X 2 LCD
- ADC
- Motor Driver
- RS232
- EEPROM
- Cables
- Connectors
- Serial Port Lead
- e-Learning Software
- e-Datasheets
- HandyProg Programming software
- IDEs for code writing
- Application source code

Assembled Order Code: EEDT - **£89.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

DC Motor Speed Controller (100V/7.5A)



Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied.

Dimensions (mm): 60Wx100Lx60H.

Kit Order Code: 3067KT - **£13.95**

Assembled Order Code: AS3067 - **£21.95**

PC / Standalone Unipolar Stepper Motor Driver

Drives any 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps max. Provides speed and direction control. Operates in stand-alone or PC-controlled mode. Up to six 3179 driver boards can be connected to a single parallel port. Supply: 9Vdc. PCB: 80x50mm.

Kit Order Code: 3179KT - **£12.95**

Assembled Order Code: AS3179 - **£19.95**

Bi-Polar Stepper Motor Driver

Drive any bi-polar stepper motor using externally supplied 5V levels for stepping and direction control. These usually come from software running on a computer.

Supply: 8-30Vdc. PCB: 75x85mm.

Kit Order Code: 3158KT - **£17.95**

Assembled Order Code: AS3158 - **£27.95**

Bidirectional DC Motor Controller



Controls the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The

range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.

Kit Order Code: 3166v2KT - **£17.95**

Assembled Order Code: AS3166v2 - **£27.95**

AC Motor Speed Controller (700W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or single phase 230V AC motor rated up to 700 Watts.

Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.

Kit Order Code: 1074KT - **£12.95**

Assembled Order Code: AS1074 - **£18.95**

Box Order Code 2074BX - **£5.95**



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Electronic Project Labs

Great introduction to the world of electronics. Ideal gift for budding electronics expert!

500-in-1 Electronic Project Lab

Top of the range. Complete self-contained electronics course. Takes you from beginner to 'A' Level standard and beyond!

Contains all the hardware and manuals to assemble 500 projects. You get 3 comprehensive course books (total 368 pages) - *Hardware Entry Course*, *Hardware Advanced Course* and a microprocessor based *Software Programming Course*. Each book has individual circuit explanations, schematic and connection diagrams. Suitable for age 12+.

Order Code EPL500 - **£149.95**

Also available - 30-in-1 **£16.95**, 130-in-1 **£39.95** & 300-in-1 **£59.95** (details on website)



Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Professional Digital Multitester (9 Function inc Temperature)

High quality DMM offering 31 ranges and 9 functions (see table below for full details) and adjustable LCD screen for easy viewing.

Supplied with shrouded test leads, K type temperature probe, shock-proof rubber holster, built-in probe holder & stand.



Large 36mm digit adjustable LCD display • Auto power OFF • Data hold • Automatic polarity indication • Low battery indication • Audible continuity test • Transistor hFE and diode test

Technical Specifications

DC voltage: 200mV-1000V • AC voltage: 2V-750V • DC current: 20mA-10A • AC current: 20mA-10A • Resistance: 200Ω-200MΩ • Capacitance: 2nF-20uF • Temperature: 0 - 1000°C • Max display: 1999

Order Code: DMM225 - Was £31.95

Now on sale at just **£21.95!**

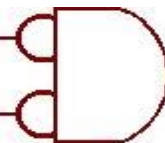
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Compact Control Design



Compact Control Design has a range of off the shelf products designed to meet your control, monitoring and acquisition needs. All products use the latest technology to provide top performance in a small size and at a low cost. We also provide a full hardware and software design service.

P0701 USB PIC

USB 2.0 interface. Can be bus powered or self powered. Powerful PIC18F4580 Microcontroller running at 40MHz. Up to 10MIPS performance.

All microcontroller I/O pins available except RA6, RA7 (oscillator) and RC6, RC7 (serial port).

Bootloader pre-programmed and download software included, enabling quick and easy programming of applications.

No need for a separate programming device.

Many example applications and firmware available, see Compact Control Design download page.

Connector has standard 40 pin 0.1" pitch 0.6" wide footprint. High quality tuned pin connectors suitable for most IC sockets and prototyping boards.



Compatible with Microchip's MPLab 'free of charge' programming environment. Libraries and linker scripts included to support assembler programs (MPLab) and popular compilers.

**PRICE:£26.00
+ VAT**

P0704 Developer Board

The P0704 developer board is an ideal way to get started with our USB-PIC module and motor driver modules. All of the USB-PIC module I/O signals are available through screw terminals making connections to sensors, switches, lamps, relays etc. easy. Ports B & E (11 I/O signals) can also be configured with pull-ups and input filtering suitable for connection to limit switches, home position sensors etc. The board supports up to 4 motor driver modules, each module position accepts either a Stepper motor module or a DC motor module. The board allows bus-powered or self powered operation of the USB-PIC module & includes a P0615 mini regulator so only a single power supply is required for the motor driver modules.



All options are configured using jumpers, and stepper motor drive current can be easily adjusted for each module by variable resistors. All connections are made by high quality screw terminals. The board has been designed to accommodate other driver modules as they become available.

**PRICE:£55.00
+ VAT**

P0613 DC Motor

Pulse width modulation control for DC motors, electro-magnets etc.

It has a motor supply voltage of 8 to 36V.

The maximum drive current is 2.5 Amp.

There are pulse and direction inputs.

The PWM control is up to 100KHz.

Mode input for controlling motor braking

and sleep input for power saving.

There is built in short circuit and over

temperature protection, a fault output pin

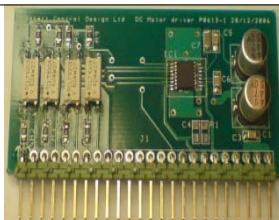
activates if either of these is detected.

No heat sink is required.

The board has dimensions of 66x30mm and is 12mm high.

There is an adapter available providing easy to use screw terminals for all connections.

All the control inputs are opto-isolated.



**PRICE:£14.00
+ VAT**

P0612 Stepper Motor Driver

The unit has a motor supply voltage of 5 to 30V. The maximum drive current per phase is 750mA.

It has current mode control.

The drive current is controlled with a resistor.

It has a selectable step size of full, half, 1/4 + 1/8.

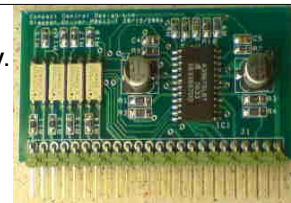
There is a step frequency of 0 to 200KHz and reset and sleep inputs for initialization and power saving.

It is a compact size with dimensions of 66x32mm by 12mm high.

The P0612 does not require a heat sink.

There is an adapter available which provides easy to use screw terminals for all connections.

All the control inputs are opto-isolated.



**PRICE:£15.00
+ VAT**

MonCon

MonCon is a product range intended to form the intelligence at the heart of any equipment from bench-top scientific instruments, production equipment, ATE etc. up to large process control systems.

The MonCon range takes a new approach to monitoring and control by using modules that encapsulate a complete task, such as the stepper motor controller module that includes all inputs and outputs necessary to form a complete stepper motor controller/driver including encoder feedback.

The general purpose modules, such as the Analogue input board are designed to be customized at minimum cost. We can supply such modules to your requirements at little or no additional cost.

The MonCon range is based on a collection of modules, each performing specific and well defined tasks. All modules plug into a back plane which provides power distribution, intercommunication and incorporates the necessary connectors linking the MonCon system to the rest of the equipment.

The modules and backplane connectors have been designed to simplify the interconnection requirements within your equipment.

Most devices, such as stepper motors, sensors etc. are wired to the MonCon backplane directly with no splices or links so the wiring loom is simplified, cheaper to manufacture and more reliable.

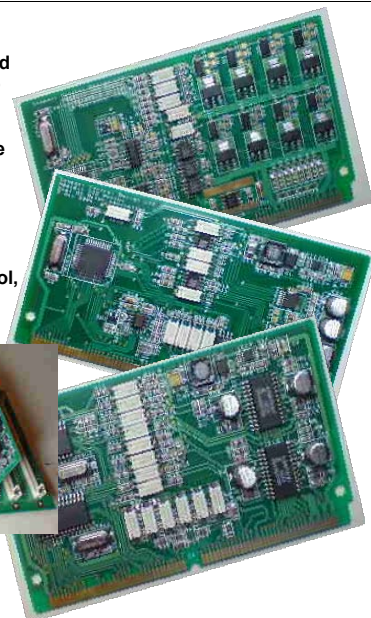
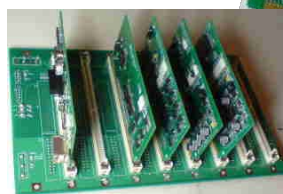
We understand that many manufacturers would want to have full control over critical parts of their products, so we are happy to allow our customers to manufacture under license.

The product range currently consists of the following - standard back planes with 4, 6 or 8 slots, controller modules for stepper and DC motors, controller modules for valves and solenoids, pressure control, flow control etc.

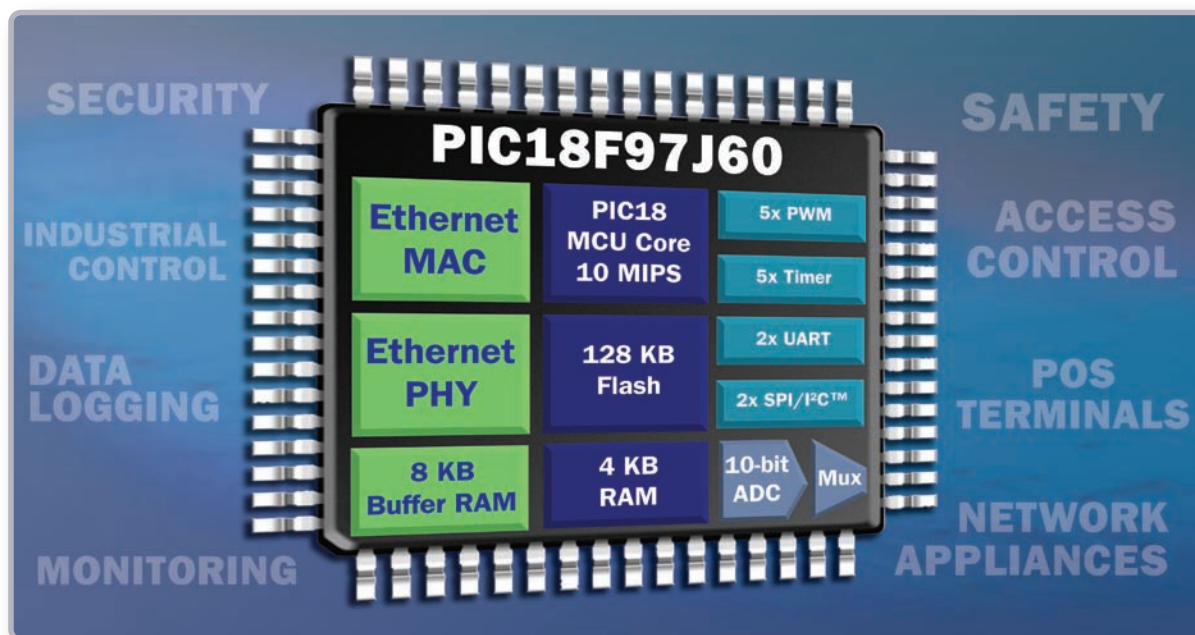
a USB interface to allow connection to a PC etc.

various I/O modules, Parallel I/O, relay output and Analogue I/O modules.

The MonCon range has been designed with flexibility in mind. Backplanes and modules to meet your requirements can generally be designed & supplied within 6 weeks of receiving a full specification.



Embedded Ethernet Solutions



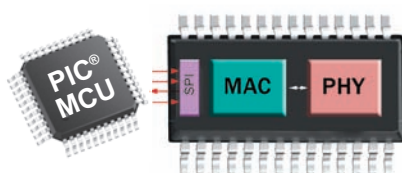
Monitor, control or re-program your application remotely using the integrated Ethernet PIC18F97J60 Microcontroller family and **FREE** TCP/IP software.

3 EASY STEPS TO GET STARTED...

1. **Learn about our Ethernet devices in 20 minutes**
Take advantage of our Ethernet web seminars.
2. **Download our **FREE** TCP/IP software**
Our TCP/IP stack is available in source code for flexible and optimized code size.
3. **Check out our low-cost Ethernet tools**
Evaluate the PIC18F97J60 family with the **PICDEM.net™ 2 Demonstration Board** (DM163024) at www.microchipDIRECT.com.

Device	Pins	Flash (KB)	Features
PIC18F97J60	100	128	10-BaseT Ethernet 12 KB RAM (8 KB dedicated Ethernet) 5x 16-bit timers 10-bit ADC, 16 channels analog comparators 2 UART with LIN protocol
PIC18F87J60	80	128	
PIC18F67J60	64	128	
PIC18F96J65	100	96	2 SPI, 2 I ² C™ Industrial Temperature -40° to +85°C
PIC18F86J65	80	96	
PIC18F66J65	64	96	
PIC18F96J60	100	64	MAC, PHY, SPI Interface
PIC18F86J60	80	64	
PIC18F66J60	64	64	
ENC28J60	28	8K RAM	

Or you may consider...



...adding Ethernet to any application with Microchip's ENC28J60 stand-alone Ethernet controller with full software support for PIC18, PIC24 and dsPIC® DSCs.

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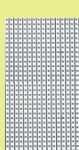
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PCB Production - Development

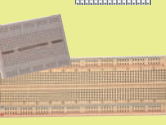
Size	Tracks/Holes	£0.24
25 x 64mm	24T / 25H	£0.87
64 x 95mm	36T / 37H	£1.41
95 x 127mm	36T / 50H	£4.39
100 x 100mm	39T / 38H	£1.40
100 x 500mm	39T / 199H	£6.20
119 x 455mm	46T / 179H	£5.40
Stripboard track cutter		£1.99



Solderless Breadboard

Tie Points & Size	Power Rails
390 81 x 60mm	£2.75
840 175 x 67mm	£4.86
740 175 x 55mm	£4.03
640 175 x 42mm	£3.08

Many other sizes available, also jump wires & matrix board.



PCB Production - Drafting Materials

A4 Artwork Film (per 10 sheets)

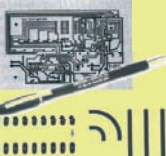
Clear Manual Film	£1.20
Clear Laser Film	£1.75
White HQ Laser Film	£4.62

Etch Resist Pens

"Dalo" Pen	£3.36
"Stichler" Fine Pen	£0.96

Etch Resist Transfers

Seno mixed DIL pads	£2.24
Seno mixed Rnd pads	£2.24
Alfac mixed pads	£1.84
Transfer Spatular	£1.25



We carry the full range of Seno & Alfac PCB transfers, see our catalogue for full details.

Soldering Irons

We carry in stock a wide range of soldering iron and soldering accessories, from 12 to 100 Watts.

20W 240V Basic	£3.74
25W 240V Ceramic	£7.14
30W 240V Basic	£4.68

Desolder Pumps

Basic 165 x 18mm	£2.85
Antistatic 195mm	£3.92
Antex Mini 198mm	£6.02
Antex Pro 210mm	£10.26



Soldering Station

A 48W adjustable temperature soldering station with a rotary dial, LED Temperature metering, on/off switch, iron holder and tip cleaning sponge. This station features accurate heat sensing for instant compensation & stable temperatures. Adjustable temperature range of 150 - 420°C, Low voltage iron with Silicone cable. Supply: 240V, Iron: 24V 48W



Model 167-540 £41.66

Soldering Station

A 48W adjustable temperature soldering station with a rotary dial, Digital Temperature Indication, on/off switch, iron holder and tip cleaning sponge. This station features accurate heat sensing for instant compensation & stable temperatures. Adjustable temperature range of 150 - 480°C, Low voltage iron with Silicone cable. Supply: 240V, Iron: 24V 48W



Model 167-570 £55.61

Digital Multimeter

Model: 121-120

Price: £11.47

A highly featured digital multimeter for professional use. Offers 30 ranges and 8 functions including temperature, capacitance, diode, continuity and hFE measurement. Large 3.5 digit LCD display with automatic polarity indicator. Supplied with shrouded test leads, K type temperature probe and shock proof rubber holster.

Technical Specifications

DC voltage	200mV - 1000V
(±0.5%)	
AC volts	2V - 700V (±0.8%)
DC current	2mA - 20A (±1.2%)
AC current	200mA - 20A (±1.8%)
Resistance	200 Ohms - 20M Ohms (±0.8%)
Capacitance	2000pF - 20µF (±2.5%)
Temperature	0°C - 1000°C (±1.5%)
Frequency	20kHz (±1%)
Max display	1999
Power supply	9V (PP3 battery)
Dimensions	88 x 173 x 40 mm



PCB Production - Processing Equipment

We carry a large range of the photographic & chemical processing equipment for PCB production, a full list with full technical specifications is available in our catalogue or visit our web site.

UV Exposure units

2 x 8W Tubes, 6 min timer	
229 x 159mm working area	
Model 332-002	£98.75
4 x 15W Tubes, 7½ min timer	
330 x 260mm working area	
Model 332-004	£209.48

Chemical Processing

Low cost plastic tray	£2.30
Process tanks feature electrically operated pumps and/or heaters with thermostat control, suitable for boards up to 320 x 260mm.	
Universal Tank with heater	
Model 333-007	£169.58
Bubble etch Tank with heater & bubble pump.	
Model 333-004	£208.48



Any of these items, carriage £5.50

PCB Production - Tools

Drill Bits

HSS parallel shank bits available in sizes from 0.3mm to 2.0mm	
0.3-0.95mm in 0.05mm steps	£0.60ea £4.00/10
1.0-2.0mm in 0.1mm steps	£0.40ea £3.60/10

HSS Reduced shank (2.35mm) bit available in sizes from 0.6mm to 1.7mm in 0.1mm steps	£0.84ea £7.60/10
--	------------------

Reground Tungsten carbide reduced shank available in sizes from 0.6 to 1.6mm in 0.1mm steps £1.90

Drilling Machines

Expo Reliant 12V drill, 3.8mm capacity, 8400rpm	£12.78
Expo Zircon 12V drill, 3.8mm capacity, 11900rpm	£14.20

Minicraft MX1 230V, 8000 - 21000rpm with chuck & collet. Model EPE270-390
Normal price £48.51



**SPECIAL PRICE
£31.02**

Servisol Products

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200ml Switch Cleaner	£2.30
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400ml Foam Cleanser	£2.13
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200ml Aero Klene	£3.33
200ml Aero Duster	£5.13
250ml Cold Clean	£3.14
200ml Label remover	£3.52
400ml Isopropyl alcohol	£3.42

Tubes

10g Heatsink Compound	£1.66
25g Heatsink Compound	£2.60
50g Silicone grease	£3.16



Bench Power Supplies

A range of single output regulated bench power supplies with variable voltage & current limiting. Features: Short circuit and "Foldback" overload protection, Metal case with on/off switch, outputs via Red, Black & Green (Earth) 4mm shrouded sockets.



Model: 461-550	0-30V0-3A	£70.88
Model: 461-552	0-50V 0-3A	£81.00
Model: 461-554	0-30V 0-10A	£135.00

Panel Meters

High quality analogue panel meters, class 2, zero point correction, mirror scale and prewired for panel illumination. Meter size 46 x 60mm, Cutout size: 38mmØ.

Range	Int
0-50µA	6k5
0-100µA	1k0
0-500µA	430Ω
0-1mA	200Ω
0-10mA	20Ω
0-50mA	1Ω
0-100mA	0.265
0-1A	60mΩ
0-3A	20mΩ
0-5A	12mΩ
0-15A	4mΩ
0-10V	10k
0-15V	15k
0-30V	30k
±50µA	1k9



All meters £5.89 each
6V Lamps £1.23 / pair

Magnifying Glass Lamp

A high quality scratch resistant magnifying glass fitted to a balanced swivel arm and desk mount. An integral fluorescent tube provides illumination. Magnification: 3x Lens: 120mmØ Tube: 22W Daylight simulation.

Model: 028-205 £28.80



New
The Electronics Shop.co.uk
Sound & Lighting
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PCB Production - Laminates

Copper clad - paper

Single sided low cost paper composite board

100 x 160mm Board	£0.54
100 x 220mm Board	£0.62
100 x 233mm Board	£1.02
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8" x 12" Board	£1.96

Copper clad - glass fibre

Single & Double 1.6mm 305g/m²

100 x 160mm Single	£1.06
100 x 220mm Single	£1.49
160 x 233mm Single	£2.29
220 x 233mm Single	£2.88
8" x 12" Single	£3.98
100 x 160mm Double	£1.09
100 x 220mm Double	£1.25
160 x 233mm Double	£2.30
220 x 233mm Double	£2.90
8" x 12" Double	£4.05



Photoresist Coated

1.6mm 35 micron Pre-coated with a high quality photoresist layer. Available in low cost paper composite or Glass fibre, Single & Double sided. Other sizes also available.

Size	Paper Single	Paper Double	Glass Fibre Single	Glass Fibre Double
4 x 6"	£1.47	£1.82	£1.89	£2.17
6 x 12"	£4.20	£5.04	£5.60	£6.23
9 x 12"	£6.30	£7.70	£8.40	£9.38
10 x 12"	£8.19	£10.01	£10.78	£11.83
12 x 12"	£8.26	£10.08	£10.99	£12.25
100 x 160mm			£2.38	£2.66
203 x 114mm			£3.01	£3.43
220 x 100mm			£3.08	£3.71
233 x 100mm			£4.83	£5.92
233 x 220mm			£6.83	£7.70

PCB Production - Chemicals

100ml Aerosol Photoresist spray, covers 2m²	£4.62
50g Powder developer, makes 1lt	£1.09
500g Powder developer, makes 10lt	£7.08
250g Ferric Chloride Pellets, makes 500ml	£1.68
500g Ferric Chloride Pellets, makes 1lt	£3.04
2.5kg Ferric Chloride Pellets, makes 5lt	£9.84
1.1kg Clear Fine etch crystals, makes 5lt	£17.58
90g Tin Plating Powder, makes 1lt	£11.58
200ml Aerosol Flux spray	£3.41
110ml Aerosol PCB Laquer spray	£3.54

Tools - Cutters & Strippers

We carry a wide range of specialist tools for the electronics industry including:

Side Cutters

130mm Low cost	£1.99
115mm Draper	£2.38
115mm Box Jointed	£4.26
145mm Long reach	£3.40

Wire Strippers

130mm Low cost	£2.30
150mm Draper 5mmØ	£5.86



Tools - Ratchet Crimping Pliers

High quality ratchet crimping pliers for various terminals including Automotive, Data, Power and Data connections.

Red / Blue / Yellow	£15.80
BNC / TNC RF series	£15.08
RJ11/12 Data Series	£22.32
RJ45 Data Series	£20.43
RJ11/12 & 45 Series	£11.83

CKK Tools Crimp Pliers

Green/Red/Blue	£24.38
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0.5-6.0mm² crimps	£26.01
Non insulated crimps	£24.38



Cable - Ribbon

7/0.127mm Grey ribbon cable on a 0.05" 1.27mm pitch with a red identifying stripe. Supplied by 305mm (1ft) or on full 30.5m (100ft) reels.

Size	per 305mm	per Reel
10 Way	£0.10	£3.10
14 Way	£0.14	£7.50
16 Way	£0.16	£8.58
20 Way	£0.20	£10.72
26 Way	£0.26	£13.94
34 Way	£0.34	£18.22
40 Way	£0.40	£21.44
50 Way	£0.50	£26.80
60 Way	£0.64	£33.92
IDC Crimp tool		£10.60



CAT5e Networking

UTP Cable
Conforms to CAT5e
100MHz standard
ETA verified TIA/EIA 568-B.2

305m Box	£45.31
100m Reel	£22.28
exc carriage.	



RJ45 Outlet Kit

Backing Box	
2 Gang Plate (2 Mods)	£0.50
RJ45 Module	£0.75
Blank Module	£0.25
1 Module Blank	£0.35
2 Module Blank	£0.45

Coloured id inserts. £2.99ea £2.42 (10+)

Tools

Plastic punch down tool	£1.40
& cable stripper	
Professional punch down	
IDC & trim tool	£7.38



Outlets

CAT5e Outlet Module	£1.70
1 Gang Plate (2 Mods)	£0.50
2 Gang Plate (4 Mods)	£0.75
1/2 Module Blank	£0.25
1 Module Blank	£0.35
2 Module Blank	£0.45

Other keystone outlets, switches & accessories available. Patch & Cross-over leads from £0.50

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Teach-In

Another two years and another *Teach-In* series starts – this one subtitled *Using PIC Microcontrollers*. It hardly seems more than a few months since *Teach-In '06* (which is now available in book form, together with a free interactive CD-ROM – see our *Direct Book Service* for ordering details, or pick up a copy at larger branches of WHSmith). This new *Teach-In '08* series has been specially written by our Consulting Editor John Becker, who draws on his many years of experience in producing PIC projects and features for *EPE*. John actually wrote our first PIC tutorial series back in 1998 and our first PIC programmer was published in Feb 1996, yet somehow microcontrollers still seem like a new concept to some readers. Microchip (the manufacturers of PIC microcontrollers) tell us they have now supplied over five billion PIC chips.

PIC projects

The new series employs John's tried and trusted *Toolkit TK3* software for PIC programming and is based around a series of breadboard projects that take readers step-by-step through the development of the software. Starting off with control of a single LED and developing the various concepts and techniques from there. Progressing through multiple LED control, alphanumeric liquid crystal displays for event counting, then frequency counting and a 24-hour clock etc.

Other microcontrollers

While we have mainly concentrated on using PIC microcontrollers in our projects, as opposed to other types, we do now publish a few microcontroller projects that are not PIC-based and we intend to do a brief introduction to AVR microcontrollers in a future issue.

Mike Kenward

AVAILABILITY

Copies of *EPE* are available on subscription anywhere in the world (see opposite) and from all UK newsagents (distributed by SEYMOUR). *EPE* can also be purchased from retail magazine outlets around the world. An Internet on-line version can be purchased and downloaded for just \$18.99US (approx £9.50) per year, available from www.epemag.com

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PROJECTS AND CIRCUITS

All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it. A number of projects and circuits published in *EPE* employ voltages that can be lethal. **You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.**

COMPONENT SUPPLIES

We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment, as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.



Christmas Innovations

Barry Fox looks at some new products released for the Christmas market

Every August the consumer electronics companies stage 'Christmas is coming' events to unveil new technology that will be in the shops for December. This year the two Korean rivals, LG and Samsung, staged an uneasy truce.

Samsung and LG

Samsung showed in the centre of London, and LG took over the Arsenal football stadium, inconveniently located far away in North London – but LG showed later in the day to give journalists time to get from one event to the other. Both events disappointed.

LG showed very little that was new and many products were not even switched on. The over-priced and under-featured MultiBlue dual Blu-ray/HD-DVD recorder sat dead under a TV and a new sub-£100 portable DVD player (which also plays movies recorded in DivX MPEG-4 format from burned disc or USB stick) was not playing either.

Samsung

Samsung is following the trend created by Panasonic, with camcorders that record video to SD or MMC memory card. So there are no moving parts, for smaller size, better water and dust resistance and less battery drain. The camera is ready to shoot in just three seconds too. The HMX10 is claimed to be the 'world's smallest 50fps HD camcorder', and costs £500. It has a 10x optical zoom lens with image stabilizer but measures only 67.5 x 61.5 x 117.5mm (with volume of just under 500cc and weight just 310g).

Samsung claims two hours of 720p HD recording on an 8MB card, but the camcorder was not on show and there was no information available on whether Samsung has adopted the new AVCHD recording standard developed by Sony and Panasonic.

The very slightly smaller MX10 camcorder costs £200 and records two hours of 576 interlaced Standard Definition video in a 4GB card. The days of tape are clearly numbered. Although Samsung has promised a dual standard blue laser disc player with fuller features than the LF MultiBlue, it was not on show.

Yamaha

Japanese music and electronics company Yamaha has commercialized the DSP (Digital Sound Projector), system

invented by British startup 1 Ltd. A single long box, which sits under a widescreen TV, houses several dozen tiny speakers that fire beams of sound round the room. The beams have slightly different signal delays introduced by individual digital amplifiers. The delays steer the beams so that the listener hears centre sound direct from the DSP box and surround sound bounced off the room walls. The result is a good approximation of surround sound, without the need for speakers round the room.

The new YSP-500 breaks the £500 barrier; sixteen 2W beam drivers work with two 15W woofers. Larger, more expensive DSP models use 21 or 40 beam drivers. The YSP-40D (at £1200) cleverly incorporates video up-scaling circuitry which up-converts Standard Definition analogue signals to 1080i or 720p HD, while converting the analogue to digital video for feeding to an HD-Ready TV set by HDMI cable. Because the speaker box has built-in amplifiers, it can also connect to an MP3 player or optional iPod dock.

Belkin

Accessory manufacturer Belkin is picking up on mounting consumer disquiet over the yawning gap between the broadband speeds promised by ISPs, and the real speeds they deliver down the line. The new N1 Vision Router comes in stylish black gloss and has an LCD screen display that shows the actual data transfer speed on the line.

Although computer geeks can already use computer software such as Network Magic, to analyse line speeds, this requires some skill and involves using a PC to run a test file transfer. The Belkin Router continually runs its own tests, analyses the results and displays them on screen.

The screen displays both download and upload speeds. This is useful because although ADSL broadband (asymmetric digital subscriber line) routinely offers slower speeds for upload than download, on the principle that most people are using broadband to download files and web pages, a crawling upload speed can also slow download because the PC is continually waiting for handshakes and confirmations.

The N1 will make it much easier for consumers to complain to their ISPs, with hard facts to back up frustration.

An N1 router with built-in DSL modem and WiFi will cost around £150.

Company 3

3G cellphone operator 3 will soon launch what the world, especially the student world, has been waiting for; a simple, small USB modem for a laptop that has a built-in SIM card for broadband data connection. The HSDPA (High Speed Downlink Data Packet Access) system squeezes 3.6Mbps from 3G UMTS, which is faster than most fixed line DSL can offer. The system will be ideal for students whose digs have no broadband line, but also useful for business travellers who must currently hunt for WiFi hotspots and for families who have moved house and then have to wait for a DSL line to be installed.

The modem is essentially a stripped down cellphone, not able to make speech calls, and designed solely to let the laptop connect to the Internet. But of course the laptop can then be used with VOIP services like Skype to make speech calls.

3 has not yet said how much the service will cost. Currently, using a SlingBox video streamer, to relay signals from a home Sky box to a video cellphone, costs £10 a month on top of the basic £15 a month for speech. A spokesman for 3 acknowledges that '£25 a month would indeed be too much for students'.

Price Grabber

With so much new gadgetry on offer, consumers inevitably shop around for the best price. PriceGrabber (www.pricegrabber.com/) is one of several websites that offer online price comparisons. The company has now hit on a clever way to exploit the information it collects on who is searching for which new product. The number of people who search for a product gives a good indication of the number of people who are likely to buy the product, from one source or another. This data can be used to gauge the likely success of a new product even before it goes on sale.

PriceGrabber says that data collected from price comparison searches ahead of the Wii, Xbox 360 and PS3 games system launches gave an early insight into the runaway success of Nintendo's Wii over the competing systems from Microsoft and Sony.

New Brunning Training Course

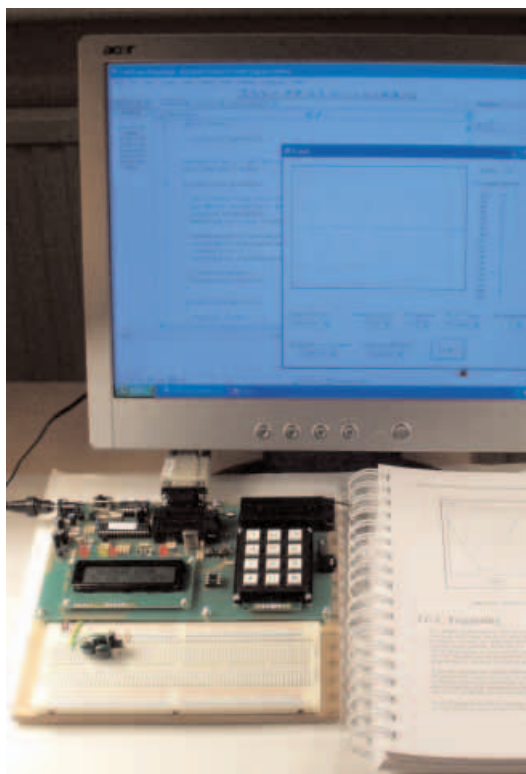
Brunning Software have announced a new training course which combines PIC training and Visual C training into a single course. For the new course the Brunning Software PIC programmer, as well as being able to programme a test PIC in the ZIF socket, has been given the ability to write experimental code into its own control PIC.

Previously, the control PIC handled just the programming and timing requirements but by being able to write Brunning's code into this PIC their programmes have direct access to the serial port, which will already be connected to the PC. This creates a very simple system for being able to experiment with serial communication between a PC and an external circuit.

The new course consists of three full-size text books, the programmer module, CD of software and four test PICs for the experiments. The first book starts at absolute beginner level to teach PIC programming in assembler. The second book teaches PIC C programming. The third book teaches serial communication between a PIC circuit and a PC, starting with PC assembler then using Visual C#.

The book text of the experimental code and all the software needed, except for Visual C#, are on the supplied CD. The third book gives details of how to download the free edition of Visual C# from the Microchip website. The programmer module is supplied programmed ready to respond to the experimental Visual C# programmes, including collecting and sending data to function as an audio oscilloscope with sophisticated triggering.

The total price for the PH27 training course is £195.00 plus postage. Browse www.brunningsoftware.co.uk or Tel: 01255 862308.



Velleman Kits Cat

If you are looking for a different type of project to build or want to add to an existing completed one, you need to get hold of a Velleman Kit catalogue. So say ESR Electronic Components, who are now offering the full range of kits and modules by Velleman NV.

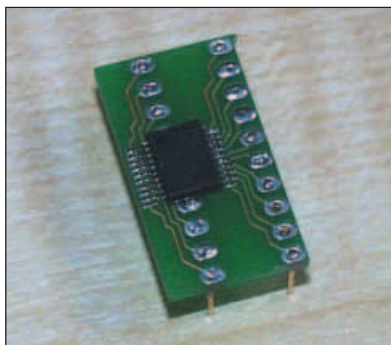
The range of projects in the catalogue cater for the experienced constructor, or for the complete novice. Kits included are amplifiers, automotive projects, control/interface devices, PIC programmers, measurement/test equipment, timers and power supplies.

With Velleman's range of mini-kits and ready-assembled modules the catalogue is certainly worth a look. To obtain your free copy, get in touch with ESR Electronic Components. Tel: 0845 2514363. Fax: 0191 2622296. Email: sales@TheElectronicsShop.co.uk. Or visit website (www.esr.co.uk/velleman) and download your own copy.

ENERGY METER

Following the publication of the *Energy Meter* project in the May and June '07 issues, the supply of the DIL version of the special 'Active Energy Metering IC' (ADE7756AN) dried up and Magenta Electronics were unable to obtain chips to supply to readers.

Obviously, this prevented the project being built, but Magenta have come to the rescue by mounting a surface mount IC on a specially made carrier to form the DIL version shown below. It is now available from Magenta – see their advert in this issue for contact details – for £7.99 including VAT and postage.



Linux USB Data Logger

Pico Technology has announced the introduction of a, free of charge, Linux driver for the USB TC-08 thermocouple data logger. It is a beta version of a Linux driver to allow programmers to control the USB TC-08 using their own software. As Linux is widely used in educational/scientific computing, this driver is expected to open up a range of new applications for low-cost, accurate temperature data-logging.

The USB TC-08 is an 8-channel thermocouple data logger with a USB interface. It is packaged in a robust, compact case and draws its power from the USB cable, so it requires no external power supply. It has standard thermocouple connectors that accept all common thermocouple types – B, E, J, K, N, R, S, T – allowing you to measure temperatures in the range -270 to +1820 degrees Celsius with up to 0.5 degree accuracy. The TC-08 has automatic cold-junction compensation, and conversion time is 100 milliseconds per channel.

The driver is supplied in source-code form to allow compatibility with the widest possible range of Linux systems, and is accompanied by example programs in C and C++. It is released under an open source licence, which allows it to be modified and redistributed.

This beta release is not fully tested. It can be downloaded from <http://labs.picotech.com>. All drivers and documentation from Pico are free of charge.

Enquiries to Pico Technology Ltd, The Mill House, 205-207 Cambridge Street, St Neots PE19 1QB.

Tel: +44 (0)1480 396 395. Fax: +44 (0)1480 396 296. Web: www.picotech.com.

Witricity: Is Tesla's Dream Coming True?

The maverick scientist Nikola Tesla claimed he had discovered a means for transmitting electric power on an industrial scale over vast distances. Nobody ever managed to replicate his alleged demonstrations, but wire-free power distribution is back in the news now. Mark Nelson investigates these new beginnings.

Electricity transmission without wires is not a fantasy, as anyone who has witnessed a thunderstorm can testify. But is it feasible to direct usable electric power from one place to another?

For the proponents of 'witricity', the answer is a resounding 'yes'. Assuming they are not dreaming, is wirefree electricity a stunt or are there practical applications for mains without the cord?

Bothered by a beep

'Witricity' is not brand new. In fact it's a whole year since Marin Soljacic, an assistant professor at Massachusetts Institute of Technology, first described the work that he and his colleagues had conducted into wire-less power transmission. According to the MIT's press office, Soljacic was fed up with being woken at 3am by the low-battery alarm beep of his cellphone. In his words, "It occurred to me, wouldn't it be great if this thing charged itself?" and began to wonder if he could apply known principles to make new ways of transmitting energy.

The principle underlying witricity is non-radiative and relies on induction. In fact, there are already electric toothbrushes on sale that use this principle over a very short range to recharge their internal batteries. To quote MIT once more, Soljacic had the same idea and realised that the close-range induction taking place inside a transformer – or something similar to it – could potentially transfer energy over longer distances, say, from one end of a room to the other.

Wireless power

Instead of irradiating the environment with electromagnetic waves, a power transmitter would fill the space around it with a 'non-radiative' electromagnetic field. Energy would only be picked up by gadgets specially designed to 'resonate' with the field. Most of the energy not picked up by a receiver would be reabsorbed by the emitter.

The range of non-radiative wireless power is fairly restricted, measured in a few metres of the power source. Currently, Soljacic's team calculates that you would need a separate power source in each room to provide coverage throughout your home. Even then, the power transfer capability would be confined to laptop computers and mobile phones, possibly also robot vacuum cleaners. But these are early days and this might yet be the first step in the quest for a power cord-free world.

In June, the team from MIT actually managed to power a 60W light bulb by sending

energy to it wirelessly from seven feet away and announced that it hoped to release technology for commercial applications in about five years' time (see <http://news.bbc.co.uk/2/hi/technology/6725955.stm> for detailed report).

Going global

If lighting a lamp bulb seven feet away sounds a bit puny, how about global power transmission? Back in November 2002 a worldwide think-tank body predicted that wireless energy transmission could be part of a clean, abundant energy future. The Millennium Project of the American Council for the United Nations University announced that in order to meet the world's growing appetite for energy without environmental damage, electricity should be converted to microwaves, beamed over long distances by satellite, and then reconverted back to electricity.

"Instead of exporting oil in giant tankers, Saudi Arabia, Kuwait, Venezuela and other oil-producing nations could use their own oil and gas that is currently flared away to produce electricity locally and then beam it by satellite to other countries' receivers attached to local power grids. This has the great benefit of reducing potential catastrophic oil spills, managing pollution more locally, and eventually opening up new energy sources such as solar panels in Earth orbit", enthused Jerome Glenn, Millennium Project director.

He did not disclose which technology would make this feasible, but US space research body NASA was collaborating with two other bodies to make funding available for research into wireless energy transmission. National Science Foundation Program Director Dr Paul Werbos said the long term goal would be to beam down solar energy from space to remote sites all over the world. This technology would provide "an affordable source of base-load electricity without producing either carbon dioxide or nuclear proliferation", he said.

Spark transmissions?

There is another kind of wire-free power transmission that is very effective, as medium wave radio station KKOL in Seattle, Washington (USA) knows only too well. The religious broadcaster, which radiates 50kW, faces having its transmitting licence rescinded in what has been tagged one of the most unusual NIMBY (not in my back yard) cases in the world of radio transmission.

The complainant is US Oil, which operates an offloading facility in the seaport about half a mile from the transmitter site.

It claims KKOL's signal is strong enough to draw electric arcs as workers unload crude oil from tankers. The transmissions also interfere with sensors at the refinery and the refinery's phone system, it is claimed. A spark could ignite fuel vapours or the fuel itself being unloaded, the oil giant argues.

For its part, the radio station has offered to reduce electric arcs as workers unload crude oil from tankers. The transmissions also interfere with sensors at the refinery and the refinery's phone system, it is claimed. A spark could ignite fuel vapours or the fuel itself being unloaded, the oil giant argues.

What's in a name?

Reverting to 'witricity' for a moment, who invented this catchy name? The answer is Dave Gerding, founder of the online marketing company Versive, who imaginatively coined both witricity and etricity in 2005 for a different wireless electricity project that remains on the drawing board. He was shrewd enough to register web domains in both of those names, although they have not yet found a creative use.

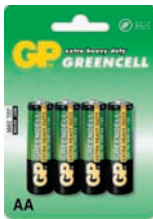
'With electromotive impulses not greatly exceeding fifteen or twenty million volts, the energy of many thousands of horsepower may be transmitted over vast distances, measured by many hundreds and even thousands of miles', wrote Nikola Tesla in US patent no. 645,576 (www.pat2pdf.org/patents/pat645576.pdf). This document from 1900 described an entirely new method of transmitting electrical energy from a generating station at very high voltage by conduction through the earth and air for use at a distant point.

It would not be difficult to fill the entire page count of this magazine with a dissertation on the feasibility of his scheme, but I'll leave this to others better qualified. One such person is Ed Phillips, whose comments are listed at www.pupman.com/listarchives/2005/Jul/msg00589.html. His most telling comment is this: 'Figuring out how to bill correctly and how to disconnect non-paying customers ... alone could make the difference between a practical system and one that was useless.'

Tesla never managed to create wireless electricity on this scale, although in a later experiment using his 'magnifying transmitter' at Colorado Springs he claimed to have lit 10,000 watts of Edison lamp bulbs some 26 miles away.

You can read more on Tesla at www.pbs.org/tesla/index.html, in the book *Radio Tesla* by George Trinkaus and in countless other publications and websites.

Batteries



Zinc Chloride, Alkaline, NiMH, NiCD & Sealed Lead Acid batteries. We carry battery packs for racing & radio control. We also manufacture the NiCD Bot-Pack+, a high performance custom made pack with forced cooling options for the most demanding applications.

Sample pricing:

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- Racing packs from £11.95
- 12V 2.2Ah to 44Ah SLA from £6.99

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13.8V 20A power supply with Amps display £43.87

Power supplies fixed and variable voltage to 15V 40A. Chargers for NiCD, NiMH, LiPo & SLA batteries to 12V 20A.



Sample pricing:

- GP AA charger with 2 off 1300mAh cells £5.45
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DC motor speed controllers from 1A to 300A. Various interfacing options including RC, I2C, serial &

analogue voltage. Relay reversing and fully solid state H-bridge, single and dual channel variants.



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- Dual 1A motor controller £17.09
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Radio Control



A wide range of radio control products including transmitters, receivers, servos, gyros, crystals, interfaces, leads etc.

Sample pricing:

- 4-Channel 40MHz FM transmitter / receiver / crystals from £34.95

Microcontrollers



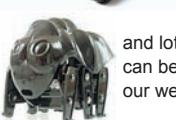
The 'PICAXE' range of programmable microcontrollers. Write in BASIC or Flowchart and download straight into the microcontroller, so no expensive programmers are required. The 8 pin version provides 5 i/o pins (1 analogue input). The 18 pin version provides 8 outputs and 5 inputs (3 of the inputs have analogue capabilities). The 28-pin version provides 9-17 outputs, 0-12 inputs and 0-4 separate analogue inputs.

Sample pricing:

- 8 pin starter kit including software, lead, battery holder, PCB & components for £9.94
- 28 pin version pictured above £21.74

Robot Kits

We carry a wide range of robot kits from BEAM to full combat and includes the very popular Robonova biped walker. Kits range in price from £16.95 to £689.05 built by enthusiasts & school pupils from all over the UK. Many are programmable via a PC, RC or autonomous. Full details of these and lots more can be found on our website.



Mechanical & Hardware



We carry a wide range of mechanical products many of which are hard to find elsewhere. Bearings from 1mm to 30mm bore. Plastic and steel pulleys, plastic and

steel gears from MOD 0.5 to MOD 2.0. Steel chain sprockets in 6 & 8mm, 3/8" & 1/2" pitch. Silver steel, EN24T steel, collets & shaft couplings. Nuts and



bolts from M2 to M12, springs, clips & Pins. Wide range of engineering materials including aluminium (6082 T6 to 12mm thick), brass tube, rod, sheet etc..

Polycarbonate sheet from 1mm to 12mm thick, PVC sheet, polymorph etc.. Wheels from 9mm to 250mm diameter.

Featured Product



We believe this to be the lowest retail priced 4-channel 40MHz FM radio control set in the UK. The set includes the transmitter, receiver and crystal pair from just £34.95. Upgrade options available.

Sample pricing:

- Transmitter, receiver and xtals £34.95
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All prices include VAT



Whilst we are an internet based company, we do have a shop where visitors are very welcome to browse.

Please check our website for opening hours and if making a long journey, we suggest phoning first to ensure stock availability. If ordering on-line, 90% of orders dispatched within 2 working days.

PayPal



Vehicle Multi-Vol

Want to monitor the battery voltage, the airflow meter or oxygen sensor signals in your car? This versatile voltage monitor can do it all and includes display dimming so the LEDs are not too bright at night. It also makes an ideal monitor for a battery charger.

There are many voltages within a vehicle that can be monitored simply by attaching a meter to the source of the signal (or voltage) to be measured. This can give the driver information about the operation of various sensors and voltages within the engine bay.

When monitoring these voltages, it is not usually necessary to obtain a precise value of the voltage but the general trend of the voltage is sufficient.

Our Voltage Monitor provides for monitoring some of the most common voltages within a car. A 10-step bargraph lights LEDs in response to the measured voltage.

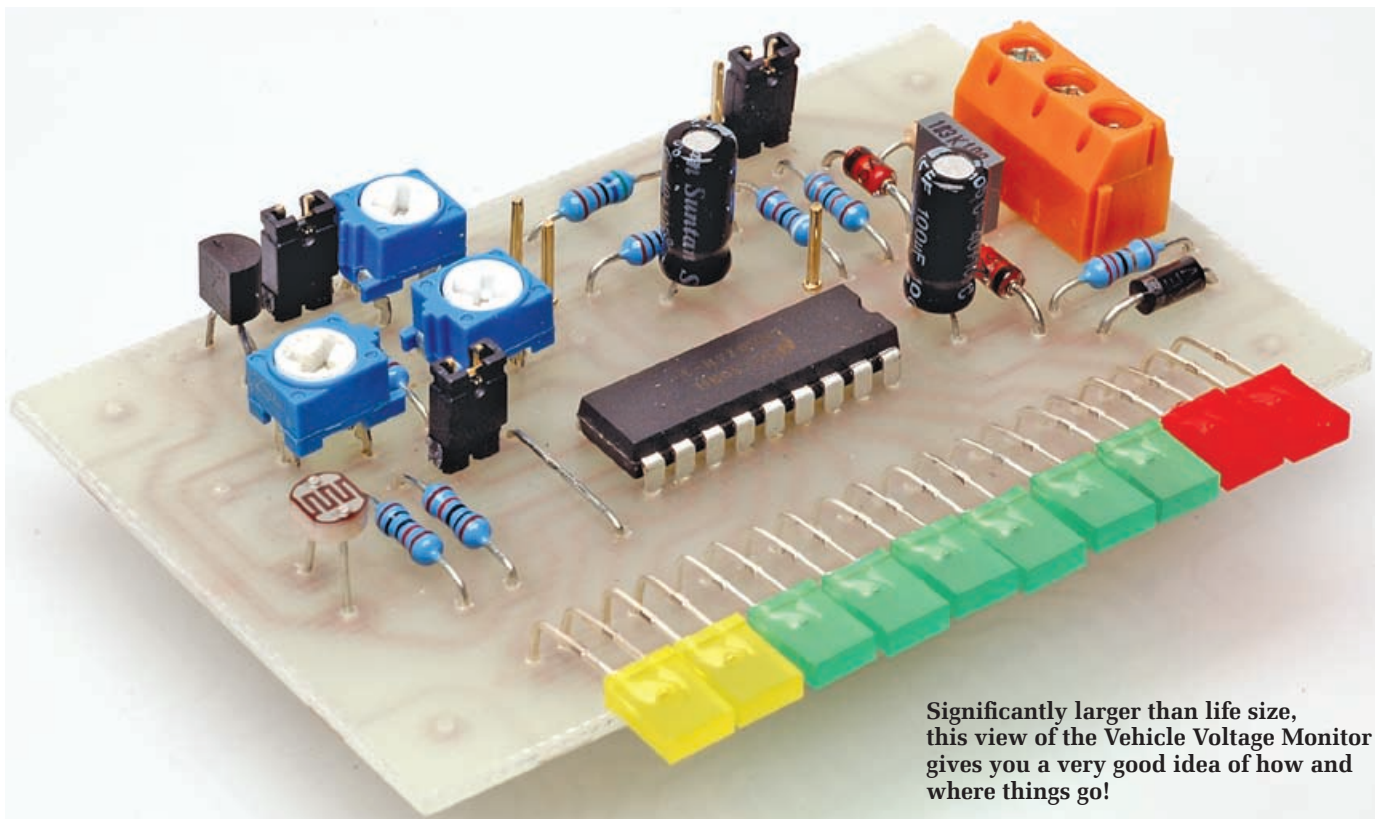
With low voltages applied to the Voltage Monitor, the low LEDs light and for high voltages, the upper LEDs light. Voltages in between are shown by the middle LEDs.

Some sensor voltages will alter simply due to the loading

of a meter. Therefore, these require a meter that does not present any appreciable load on the sensor.

For example, the oxygen sensor that is used to monitor the correct burning of the fuel, typically has a voltage output between 0 and 1V, with the mid-way voltages indicating that the fuel is burnt correctly. A low voltage (near to 0V) indicates that the air-fuel mixture is too lean and a high value (approaching 1V) indicates a too-rich mixture. The voltage from these sensors also changes at a rapid rate, as the engine management system continually monitors and changes the air-fuel mixture to ensure it is running at the correct (stoichiometric) mixture.

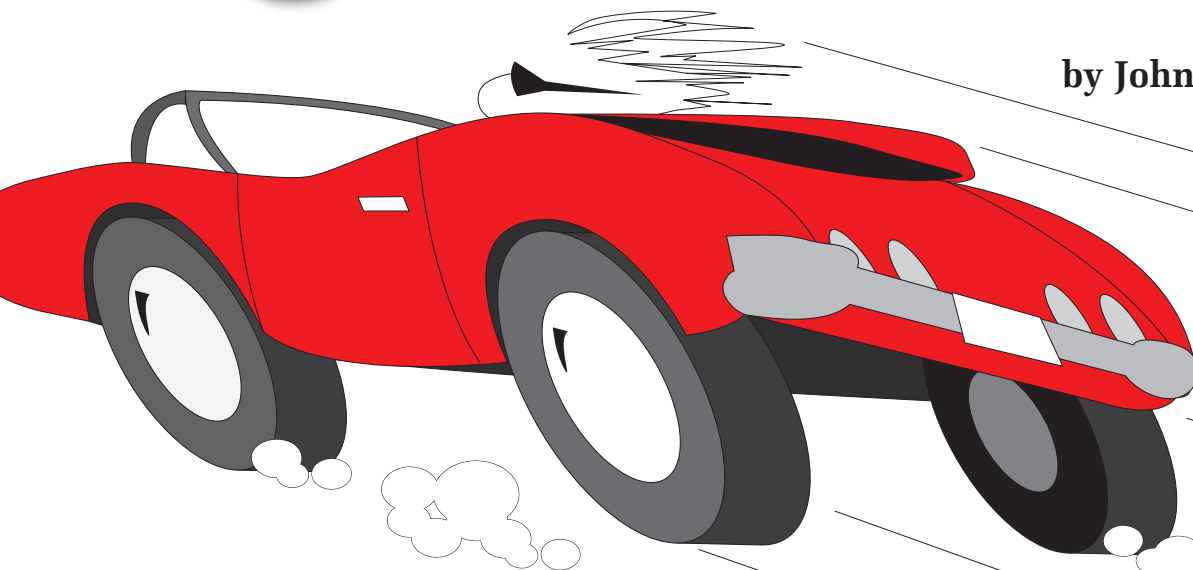
The Vehicle Voltage Monitor is easily set up to monitor a nominal 0-1V range. It also provides minimal loading on the sensor's output.



Significantly larger than life size, this view of the Vehicle Voltage Monitor gives you a very good idea of how and where things go!

Voltage Monitor

by John Clarke



A typical response curve of an oxygen sensor for rich, lean and stoichiometric mixtures is shown overleaf (Fig.2). The curve is very steep at the stoichiometric position and covers a voltage range that is typically 0.2V to 0.8V.

The stoichiometric mixture ratio is normally maintained by the engine management system to ensure minimum exhaust emissions when used in conjunction with a catalytic converter.

When the car is running you will see that the display will move rapidly up and down this steep part of the curve, as the engine management unit maintains the correct mixture. On engine over-run, the mixture may go lean. When the engine is loaded, the mixture will go into the rich portion of the curve to provide more engine power.

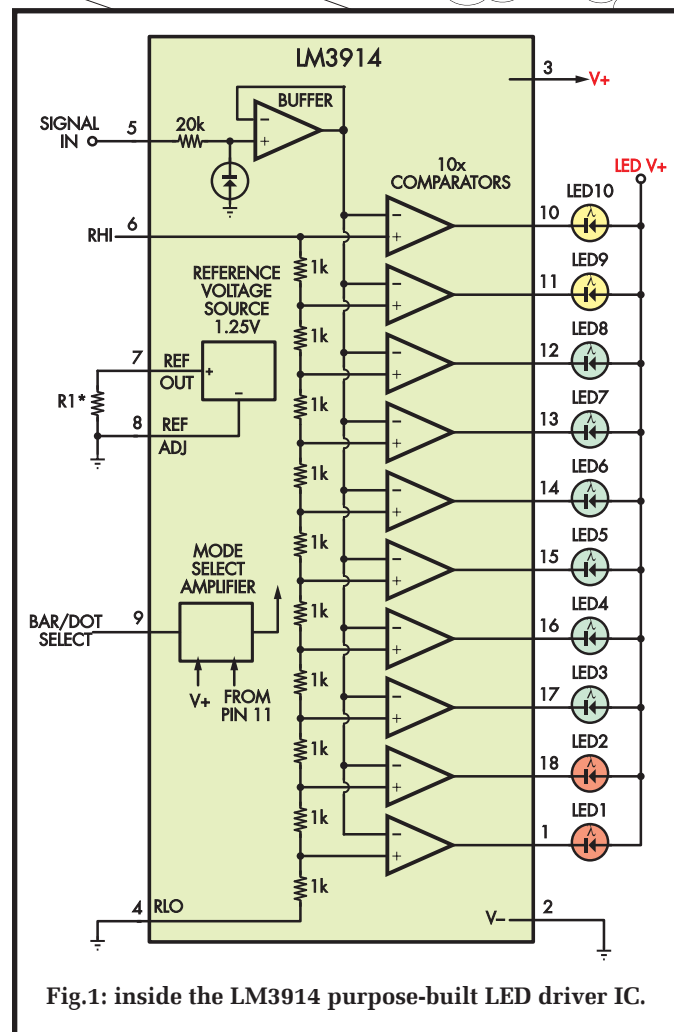
Other sensors

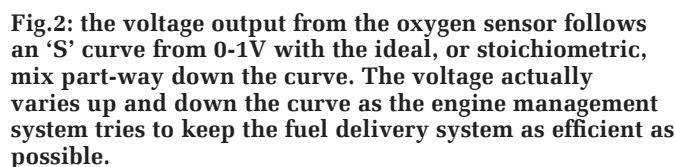
Other sensors within a car have a 0-5V range. These include airflow meters, MAP sensors and on some later models air/fuel ratio sensors. For these signals, the Voltage Monitor can be set to show the full range from 0V up to the maximum of 5V. It is also possible to narrow the voltage range that is measured and shown on the display.

For example, you may wish to monitor between 0.5V and 4.5V. To do this, it is just a simple adjustment of the upper and lower voltage limits with trimpots.

Other types of voltages that can be measured are those that do not normally drop to 0V but vary by a small amount from a typical fixed level. An example of this is the car battery. This is generally at 12V, but can fall to around 10V when the starter motor is starting the engine and rise to 14.4V when the battery is fully charged.

When measuring this narrow voltage range we are not particularly interested in what is happening below, say, 10V because it should normally never happen.





The Voltage Monitor is set to measure one of the above mentioned voltage ranges simply by selecting the correct jumper link on the PC board.

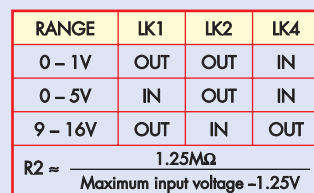
The Voltage Monitor also includes display dimming so that the display is not excessively bright at night.

Circuitry for the Voltage Monitor is based around an LM3914 10-LED linear bargraph display driver chip. This drives 10 LEDs sequentially from the lowest LED, when the voltage measured is low, through to the highest LED when the upper voltage range is reached.

Refer now to the internal diagram of the LM3914 (Fig.1). Ten comparators monitor the voltage applied to pin 5. The comparator's positive inputs are connected to 10 series-connected resistors between the $R_{L,O}$ and $R_{H,I}$ inputs. To make measurements of voltage, the $R_{H,I}$ input is connected to a voltage source, while $R_{L,O}$ is either connected to ground (0V) or an elevated voltage, if you wish to measure a range of voltages that start above ground.

When a voltage is applied to the IC's input, LED1 will light for voltages above 100mV. At 200mV, LED2 will light and so on. Finally, LED10 will light at 1V. Whether the lower LEDs remain lit, or extinguish as a higher LED lights, depends on whether the IC is set to display in bar mode or dot mode.

The LM3914 includes a voltage reference which can be used to set the R_{HI} level. This reference has a nominal 1.25V between pins 8 and 7. We can derive a 1.25V reference by connecting pin 8 to ground.



Incidentally, the current through the LEDs is set at about 10 times the current flow through R1. So if pin 7 is at 1.25V and we use a 1k Ω resistor for R1, there will be a 1.25mA current through R1. The LED current is therefore about 12.5mA. This current determines the brightness of the display.

The circuit

All this is shown in the circuit for the Voltage Monitor (Fig.3). R_{HI} and R_{LO} inputs are provided with a voltage via trimpots VR1 and VR2 that form a divider across the 1.25V reference. The divider can include a 5.6k Ω resistor if link LK4 is not connected, or alternatively, the lower end of VR2 connects directly to ground if LK4 is connected. Link LK4 gives the option of selecting an R_{LO} voltage that starts well above 0V when the link is out or providing an R_{LO} voltage that is at 0.63V or lower when the link is installed.

As mentioned, the current from pin 7 to ground sets the display LED brightness. We take advantage of this fact to include display dimming. Dimming circuitry is made up using a Light Dependent Resistor (LDR1), VR3 and the series 10k Ω resistor, transistor Q1 and the 680 Ω resistor.

It works as follows: in bright light, LDR1 has a low resistance (around 10k Ω), so the base of Q1 is pulled toward the 0V rail. Since the emitter of Q1 is only 0.7V above the base, it follows that there will be somewhere around 0.55V across the 680 Ω resistor (Reference voltage [1.25V]–0.7V=0.55V). This sets the current flow from pin 7 to ground at its maximum. Therefore, the LEDs are at their brightest in bright light.

At low light levels, LDR1 has a high resistance, so the base voltage for Q1 moves substantially higher than it was under bright light. As a consequence, Q1 is almost switched off. Current through the 680 Ω resistor is therefore minimal and the overall current from pin 7 to ground is set by the effective resistance still connected. This comprises the 10k Ω resistor and the VR1, VR2 and 5.6k Ω resistor string.

Trimmer VR3 sets the dimming threshold. At its minimum resistance, the base of Q1 will not fall below about 1.25V/2 because of the voltage divider action of the 10k Ω resistor in series with VR3 and the 10k Ω light resistance of LDR1. Thus dimming will occur even at relatively bright levels. Winding VR3 for more resistance will set the base of Q1 lower at the bright ambient light levels to increase the brightness. In practice, VR3 is adjusted to start dimming as the ambient light falls.

Signal for the pin 5 input of IC1 is processed to keep the voltage to within the 1.25V maximum range set by V_{REF} at pin 7. For the 1V signal from an oxygen sensor, the signal is passed through a 1.2M Ω resistor to provide a high input impedance load, filtered with a 100nF capacitor. Pin 5 has a very small input current, typically 25nA, so there will be less than 30mV across the 1.2M Ω input resistor. The 16V Zener ZD1 protects pin 5 from transients that could otherwise destroy the IC.

When measuring voltages above the 0-1V range, the input needs to be attenuated so that pin 5 still only sees a voltage within the 0-1.25V range. When measuring 0-5V, link LK1 is inserted so that the voltage is reduced using the 1.2M Ω series resistor and the 330k Ω resistor (R2) to ground. The division by these two resistors reduces the 0-5V signal at the input to a 0-1.08V range at pin 5. Similarly, when measuring the 16V range, link LK2 is installed to reduce the signal at pin 5 down to 1.13V. This reduction in voltage is achieved with the 91k Ω divider resistor.

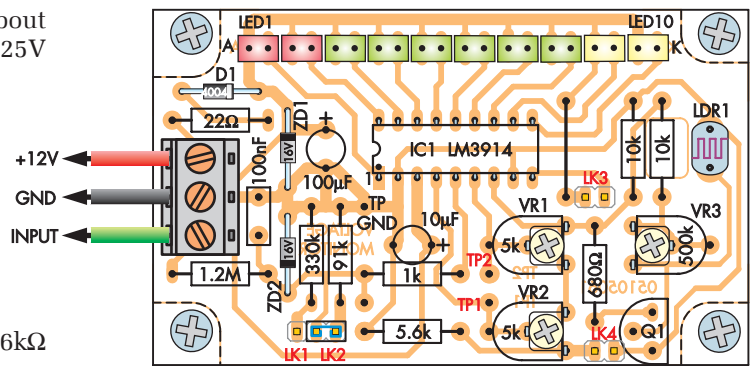
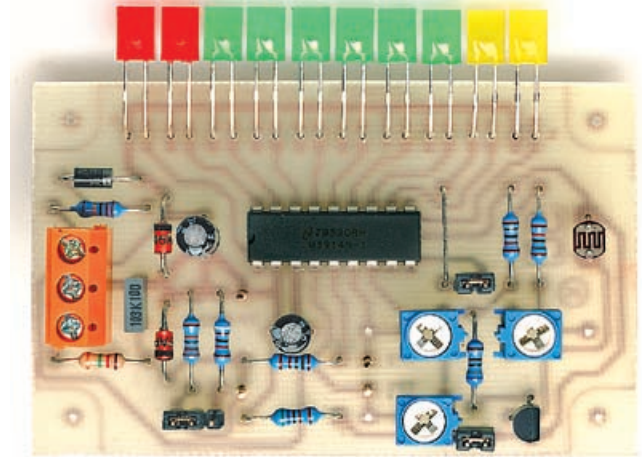


Fig. 4: here's the component layout diagram with matching photograph underneath. Take care when placing the LEDs!



For other voltage ranges, the value of the attenuating resistor will need to be calculated. To do this, take 1.25V away from the maximum expected input voltage and then divide this into 1.25mV. For example a 10V range will require a nominal 150k Ω resistor (1.25mV/(10-1.25) or 142k Ω).

The final display range is set using VR1, VR2 and link LK4. VR1 sets the point at which the maximum LED lights. VR2 sets the point which the input must reach before the first LED lights. By removing LK4, this R_{LO} level can be raised higher by including the 5.6k Ω resistor in the series string with VR1 and VR2.

Power supply

Power for the circuit is obtained from a 12V supply. This would normally be from a car battery, via the ignition switch. For other purposes, a supply from 6V-15V will be suitable. Diode D1 protects the circuit from reverse connection of the supply. The 22 Ω resistor and Zener diode ZD1 help prevent transients from damaging IC1. The 100 μ F capacitor filters the supply and also removes transients.

The 22 Ω resistor also acts to dissipate power when IC1 is connected in bar mode (when link LK3 is in circuit). In the bar mode the IC dissipates more power, so some of this power dissipation is shared in the resistor instead. It is not recommended to use the display in bar mode when the ambient temperature is above 40°C and the supply is at 15V. This is because the IC could overheat under the high temperatures and power dissipation. The IC can easily drive the display in dot mode, even on the hottest of days in a vehicle.

Parts List – Vehicle Multi-Voltage Monitor

- 1 PC board, code 642, available from the *EPE PCB Service*, size 79 x 47mm
- 1 3-way PC mount screw terminal block with 5.08mm pin spacing
- 1 LDR with 10k Ω light resistance (LDR1)
- 1 7-way pin header (broken into 2 x 2-way and 1 x 3-way)
- 3 jumper shunts
- 3 PC stakes
- 1 50mm length of 0.7mm tinned copper wire
- 1 plastic box (optional), size 83 x 54 x 31mm

Semiconductors

- 1 LM3914 10-LED linear driver (IC1)
- 1 BC327 PNP transistor (Q1)
- 2 16V 1W Zener diodes (ZD1,ZD2)
- 1 1N4004 1A rectifier diode (D1)
- 2 5mm red LEDs (LED1,LED2)
- 6 5mm green LEDs (LED3-LED8)
- 2 5mm yellow LEDs (LED9,LED10)

Capacitors

- 1 100 μ F 16V PC electrolytic
- 1 10 μ F 16V PC electrolytic
- 1 100nF (0.1 μ F) coded 104 or 100n

Resistors (0.25W, 1%)

- 1 1.2M Ω 1 330k Ω 1 91k Ω 2 10k Ω
- 1 5.6k Ω 1 1k Ω 1 680 Ω 1 22 Ω 0.5W
- 1 500k Ω horizontal trimpot (code 504) (VR3)
- 2 5k Ω horizontal trimpot (code 502) (VR1,VR2)

Miscellaneous

Automotive wire, solder.

Construction

The Vehicle Voltage Display is constructed using a PC board coded 642 and measuring 79 x 47mm. It can fit into a small plastic box measuring 83 x 54 x 31mm if required. However, our experience is that many constructors of similar projects like to mount the LEDs behind the dash, so we are presenting the unit as a bare PC board.

Begin construction by checking the PC board for any possible shorts between tracks, breaks in the copper and for holes that are not drilled. Start by installing the wire link and resistors. The accompanying table shows the resistor colour codes, but it's also advisable to check

them with a digital multimeter, as some colours can be difficult to decipher.

The diodes, transistor Q1, the capacitors and trimpots can go in next, along with IC1. Take care to orient the diodes, Q1, IC1 and the electrolytic capacitors as shown. Now install the 3-way terminal block and the two and three-pin headers for the link shorting plugs. Also insert the PC stakes at test points TP1, TP2 and TP GND.

Finally, install the LDR and the LEDs. The LDR can go in either way, but the 10 bargraph LEDs must all be installed with their anodes (the longer of the two leads) to the left.

Depending on how you wish to install the display in the car or piece of equipment, you may wish to set the LEDs parallel to the PC board. This means that you need to bend the LED leads over at 90° so that they are in line with the edge of the PC board – see photo. Alternatively, you can mount the LEDs vertically so that they later protrude through a slot in the lid of a case.

Install the links (LK1 to LK4) according to your application. A table showing the link connections for the 0-1V, 0-5V and 9-16V ranges is shown on the circuit diagram (Fig.3).

LED colours

Note that our prototype uses red LEDs for LEDs 1 and 2 and yellow LEDs for LEDs 9 and 10. This because we envisage that the most popular use for this project will be a fuel mixture meter, monitoring a vehicle's oxygen sensor. In this case, you want lean mixtures to be shown with red LEDs, indicating DANGER for your engine.

For other applications though, say monitoring your battery voltage, you might want to have red LEDs for LEDs 9 and 10, because in this case a battery voltage up around 15V indicates over-charging, another DANGER condition.

Installation

You will need to make three wiring connections to your car. It's easiest to do that at the ECU, so you will need to have a wiring diagram showing the ECU pin-outs. The four connections are: (1) +12V (ignition switched); (2) chassis (0V); and (3) sensor or car battery signal. The car battery signal is best taken at a point close to the battery for best accuracy without incurring voltage drops across the wiring in the vehicle.

Use the car's wiring diagram to find these connections and then use your multimeter to check that they're correct (eg, when you find the +12V supply, make sure that it switches off when you turn off the ignition).

In addition, you have to confirm that there is a fluctuating signal in the 0-1V range on the oxygen sensor lead (the car will need to be fully warmed up) or that the signal coming

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
□	1	1.2M Ω	brown red green brown	brown red black yellow brown
□	1	330k Ω	orange orange yellow brown	orange orange black orange brown
□	1	91k Ω	white brown orange brown	white brown black red brown
□	2	10k Ω	brown black orange brown	brown black black red brown
□	1	5.6k Ω	green blue red brown	green blue black brown brown
□	1	1k Ω	brown black red brown	brown black black brown brown
□	1	680 Ω	blue grey brown brown	blue grey black black brown
□	1	22 Ω (0.5W)	red red black brown	red red black gold brown

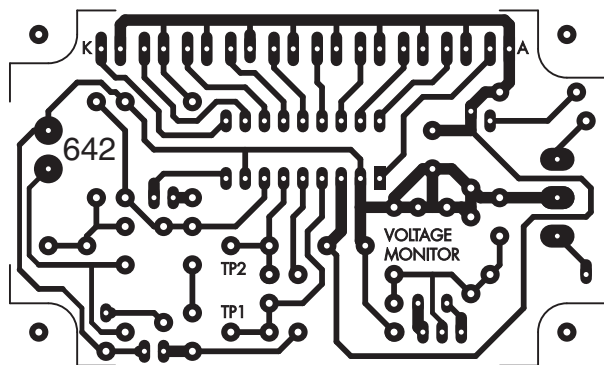


Fig. 5: full-size PC board pattern for etching your own board or checking a commercial board.

from the airflow meter, or MAP sensor changes when the throttle is blipped.

Note that the 0V connection for the Voltage Display should be made at the ECU or to a terminal that is secured directly to a chassis point.

Setting up for an oxygen sensor

Links LK1 and LK2 should be out and link LK4 installed.

- (1) Set trimpot VR1 fully clockwise and trimpot VR2 fully anticlockwise.
- (2) Start the car, let the oxygen sensor warm up and confirm that the LED display changes.
- (3) Go for a drive and briefly use full throttle. The end yellow LED should light up. Back off sharply – the end red LED should light.
- (4) Check that the LEDs travel back and forth when the engine is at idle.
- (5) If the end yellow LED never lights, even at full throttle, adjust VR1 so that it lights when the mixtures are fully rich.
- (6) In normal driving, the LED should move back and forth around the centre LED. If the oscillations are all down one end after adjusting VR1, adjust VR2 to centre the display.

Setting up for a 0-5V airflow sensor

Link LK1 should be installed and LK4 out.

- (1) Set trimpot VR1 fully clockwise and trimpot VR2 fully anticlockwise.
- (2) Adjust VR2 so that the lowest LED just lights on an

engine over-run (when you are going downhill in gear with the engine slowing the car down).

- (3) Adjust VR2 so the top LED just lights on maximum acceleration.
- (4) Repeat the adjustments, since adjusting VR1 and VR2 will affect one another to a small degree.

Setting up for a battery monitor

Link LK2 should be installed and LK4 out.

- (1) Use a multimeter to measure the battery voltage. Now with the engine running fast and with all accessories, lights etc off, set VR1 so that the top green LED lights at a measured 14.4V.
- (2) Now stop the engine and switch on the lights. Wait until the battery falls to a measured 12V and set VR2 so that the lower green LED lights.
- (3) Again, the adjustments will affect one another to a small extent so you may need to re-check the results at either end of the scale.

Adjusting the dimming

Turn the dimmer sensitivity trimpot (VR3) until the display dimming matches your preferences – clockwise will give a brighter display at night (so you need to fully cover the LDR to simulate night when you're setting it!). Note that when installing the Voltage Monitor, the LDR must be exposed to the ambient light in order for the display to dim. The LDR can be mounted off the PC board if necessary.

Note

In some cars, this Voltage Monitor will not work on some sensors. For an oxygen sensor, it needs a signal voltage from 0-1V, with the higher voltages corresponding to richer mixtures. The vast majority of cars produced over the last 15 years use this type of sensor but there are exceptions, so be sure to use your digital multimeter to check the oxygen sensor output signal before undertaking this project.

For other sensors, the output signal needs to vary in voltage. However, some airflow meters have a variable-frequency output signal and the Voltage Monitor will not work with that type of airflow meter. Again, check the output of the load sensor with a digital multimeter first.

Also note that some modern cars run stoichiometric air/fuel ratios all the time, so the rich and lean indications under acceleration and engine overrun may not be apparent on the display.

EPE

PLEASE TAKE NOTE

V2 PC Scope (Aug/Sept '07)

Parts List: Note IC15 should be a 79L05 (not 78L05), the circuit is correct.

It has come to light that the individual setup of PCs can prevent the V2 PC Scope from working with its serial control. This can be cured by installing the entire EPE Serial software from our downloads site at: <ftp://ftp.epemag.wimborne.co.uk/pub/PICS/SerialOCX/> > <ftp://ftp.epemag.wimborne.co.uk/pub/PICS/SerialOCX/> (Accessible via the 'Downloads' section on our home page at www.epemag.co.uk)

Download all the files into a temporary folder, make sure you have no other applications running (including virus checkers, email clients, Visual Basic etc) and run the SETUP.EXE and follow the prompts. This will install a copy of the OCX; and all its sub-components and correctly install and register them. The OCX software has been tested with Windows 98, 2000, ME and XP.



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Everyday Practical Electronics Featured KITS

Everyday Practical Electronics Magazine has been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are 'bullet proof' and already tested down under. All Jaycar kits are supplied with specified board components, quality fibreglass tinned PCBs and have clear English instructions. Watch this space for future featured kits.

Voltage Monitor Kit

KC-5424 £6.00 + post & packing

This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your vehicle. The kit features 10 LEDs that light up in response to the measured voltage, preset 9-16V, 0-5V or 0-1V ranges complete with a fast response time, high input impedance and auto dimming for night driving. Kit includes PCB with overlay, LEDs, all electronic components and clear English instructions.

• Requires 12VDC power

**Recommended box UB5
(HB-6015) £0.83 each**



V8 Sounding Doorbell

KC-5405 £25.75 + post & packing

Hear the rumble of a big V8 engine when visitors press the button on your doorbell. The kit also features a background noise that sounds like tappets and valves working away, for an even more realistic effect. There is a 'V' made from LEDs that light up in sync with the rumble, and the large 100mm speaker ensures that it sounds genuine. Supplied with silk screened and solder masked PCBs, silk screened and machined case, push button bell switch, speaker, wire, and all electronic components.

• As published in *Everyday Practical Electronics* Magazine October 2007



Studio 350 High Power Amplifier Kit

KC-5372 £55.95 + post & packing

It delivers a whopping 350WRMS into 4 ohms, or 200WRMS into 8 ohms. Using eight 250V 200W plastic power transistors, it is super quiet, with a signal to noise ratio of -125dB(A) at full 8 ohm power. Harmonic distortion is just 0.002%, and frequency response is almost flat (less than -1dB) between 15Hz and 60kHz. Kit supplied in short form with PCB and electronic components. Kit requires heatsink and +/- 70V power supply (a suitable supply is described in the instructions).

• As published in *Everyday Practical Electronics* Magazine October & November 2006



The Flexitimer Kit

KA-1732 £5.95 + post & packing

This kit uses a handful of components to accurately time intervals from a few seconds to a whole day. It can switch a number of different output devices and can be powered by a battery or mains wall adaptor. The kit includes PCB and all components.

• As published in *Everyday Practical Electronics* Magazine October 2007



Requires 12-15VDC wall adaptor (Maplin GS75S £10.99)

Audio Video Booster Kit

KC-5350 £31.95 + post & packing

This kit will boost your video and audio signals preserving them for the highest quality transmission to your projector or large screen TV. It boosts composite, S-Video, and stereo audio signals. Kit includes case with silkscreened and punched panels, PCB and all electronic components.

• As published in *Everyday Practical Electronics* Magazine March 2006



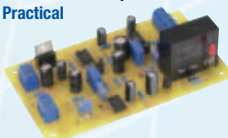
Requires 9VAC wall adaptor (Maplin #GU09K £9.99).

Delta Throttle Timer

KC-5373 £7.95 + post & packing

It will trigger a relay when the throttle is depressed or lifted quickly. There is a long list of uses for this kit, such as automatic transmission switching of economy to power modes, triggering electronic blow-off valves on quick throttle lifts and much more. It is completely adjustable, and uses the output of a standard throttle position sensor. Kit supplied with PCB and all electronic components.

• As published in *Everyday Practical Electronics* Magazine November 2006



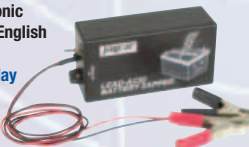
**Recommended box UB3
HB-6013 £1.05**

Lead Acid Battery Zapper Kit

KC-5414 £11.75 + post & packing

This simple circuit is designed to produce bursts of high-energy pulses to help reverse the damaging effects of sulphation in wet lead acid cells. This is particularly useful when a battery has been sitting for a period of time without use. The effects are dependant of the battery's condition and type, but the results can be quite good indeed. Kit supplied with case, silkscreened lid, leads, inductors, and all electronic components, with clear English instructions.

• As published in *Everyday Practical Electronics* Magazine July 2007

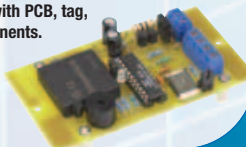


RFID Security Module Receiver Kit

KC-5393 £28.95 + post & packing

Radio Frequency Identity (RFID) is a contact free method of controlling an event such as a door strike or alarm etc. An "RFID Tag" transmits a unique code when energised by the receiver's magnetic field. As long as a pre-programmed tag is recognised by the receiver, access is granted. This module provides normally open and normally closed relay contacts for flexibility. It works with all EM-4001 compliant RFID tags. Kit supplied with PCB, tag, and all electronic components.

• As published in *Everyday Practical Electronics* Magazine August 2007



PIC Based Logic Probe

KC-5457 £4.50 + post & packing

Unlike ordinary logic probes, this one is driven by a PIC processor and operates over a wide supply voltage of 2.8VDC to 5VDC. It is extremely compact and uses surface mount devices on a PCB only 5mm wide. The probe includes a 'pulse stretcher' that will let you see very short pulses and a latch function to 'hold' infrequent pulses. Kit includes PCB and all specified electronic components including pre-programmed PIC.

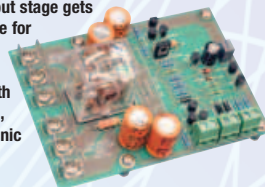
You'll need to add your own case and probe - a clear ballpoint pen and a needle work well.



Universal Speaker Protection and Muting Module Kit

KC-5450 £8.75 + post & packing

Protects your expensive speakers against damage in the event of catastrophic amplifier failure such as a shorted output transistor. In addition, the circuit also banishes those annoying thumps that occur when many amplifiers are switched on or off, especially when the volume is set to a high level. The design also incorporates an optional over temperature heat-sensor that will disconnect the speakers if the output stage gets too hot. Configurable for supply voltages between 22VDC-70VDC. Supplied with a silk screened PCB, relay and all electronic components.



Subwoofer Controller Kit

KC-5452 £29.00 + post & packing

Using this kit to control your external speaker and sub-amplifier can give you loads of bass without taking up much space. The kit has all the features you could want, including low and high pass filters, parametric equaliser and auto-turn on for external equipment. The controller is 12 volt DC powered and can also be used in automotive applications.

• Kit supplied with silk screened PCB and processed panels.



"The Champ" Audio Amplifier

KC-5152 £1.95 + post & packing

This tiny module uses the LM386 audio IC, and will deliver 0.5W into 8 ohms from a 9 volt supply making it ideal for all those basic audio projects. It features variable gain, will happily run from 4-12VDC and is smaller than a 9 volt battery, allowing it to fit into the tightest of spaces.

• PCB and all electronic components included.



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Kit supplied with case, screen printed front panel, PCB with overlay and all electronic components.



Requires 9VDC wall adaptor
(Maplin #GS74R £10.99)

4 Channel Guitar Amplifier Kit

KC-5448 £28.75 + post & packing

This is an improved version of our popular guitar mixer kit and has a number of enhancements that make it even more versatile. The input sensitivity of each of the four channels is adjustable from a few millivolts to over 1 volt, so you plug in a range of input signals from a microphone to a line level signal from a CD player etc. A headphone amplifier circuit is also included for monitoring purposes. A three stage EQ is also included, making this a very versatile mixer that will operate from 12 volts. Kit includes PCB with overlay & all electronic components.

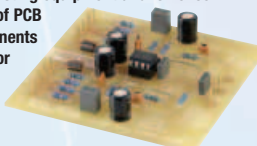


Universal Stereo Preamplifier Kit

KC-5159 £5.25 + post and packing

Based around the low noise LM833 dual op-amp IC, this preamp is designed for use with a magnetic cartridge, cassette deck or dynamic microphone. It features RIAA/IEC equalisation, and is supplied with all components to build either the phono, tape or microphone version.

- Measuring only 80 x 78 x 30mm, it is ideal for incorporating into existing equipment and is hence supplied short form of PCB and specified components plus PCB standoffs for mounting.
- +/- 15VDC required



Theremin Synthesiser Kit

KC-5295 £14.75 + post and packing

The Theremin is a weird musical instrument that was invented early last century but is still used today. The Beach Boys' classic hit "Good Vibrations" featured a Theremin. By moving your hand between the antenna and the metal plate, you create strange sound effects like in those scary movies! Kit includes a machined, silkscreened and pre drilled case, circuit board, all electronic components, and clear English instructions.



Requires 12VDC wall adaptor (Maplin #GS74R £9.99)

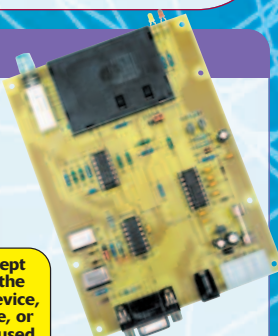
Smart Card Reader and Programmer Kit

KC-5361 £15.95 + post & packing

Program both the microcontroller and EEPROM in the popular gold, silver and emerald wafer cards. Card used needs to conform to ISO-7816 standards, which includes ones sold by Jaycar. Powered by 9-12 VDC wall adaptor or a 9V battery. Instructions outline software requirements that are freely available on the internet. Kit supplied with PCB, wafer card socket and all electronic components. PCB measures: 141 x 101mm.

• As published in Everyday Practical Electronics May 2006

Requires 9-12VDC wall adaptor
(Maplin #UG01B £13.99)



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- Height: 145mm



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- Uses 0.25W resistors with 5% tolerance



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Magnifier Headset

QM-3510 £8.50 + post and packing

Minimising eyestrain while leaving your hands free this headset gives a wide field of vision, can be worn over prescription eyeglasses and can be tilted up out of the way when not in use. Four different magnifying multiples, lightweight, excellent for close work.



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Teach-In 2008

Using PIC Microcontrollers

Part One – Introduction to PIC Microcontrollers and the Development Interface Board for this series

JOHN BECKER



TEACH-IN 2008 takes a slightly different format to previous Teach-Ins. Whereas the earlier ones have concentrated on telling you about components and how to use them in general, *Teach-In 2008* takes a specific component, a PIC microcontroller, the PIC16F628, and examines it in detail, providing you with information on how to use PICs in your own projects.

The series has been inspired by the number of readers, many of them new to reading *EPE*, who have been noting the emphasis we place on PICs and who wish to know more about how to use them.

In the past, we have published PIC Tutorials in various forms, and the last one, *EPE PIC Tutorial V2*, is still valid. That concentrated on a command-by-command examination and explanation of various aspects of PIC programming, principally in relation to the PIC16F84. The text, hardware and software for it are on our *PIC Resources CD-ROM*, periodically advertised in our pages.

Constructional examples

This *Teach-In 2008* gives constructional examples in each part of the series, explaining how to program and use a PIC16F628 in a variety of circuit types, using 'breadboarded' circuits you can quickly and easily put together yourself.

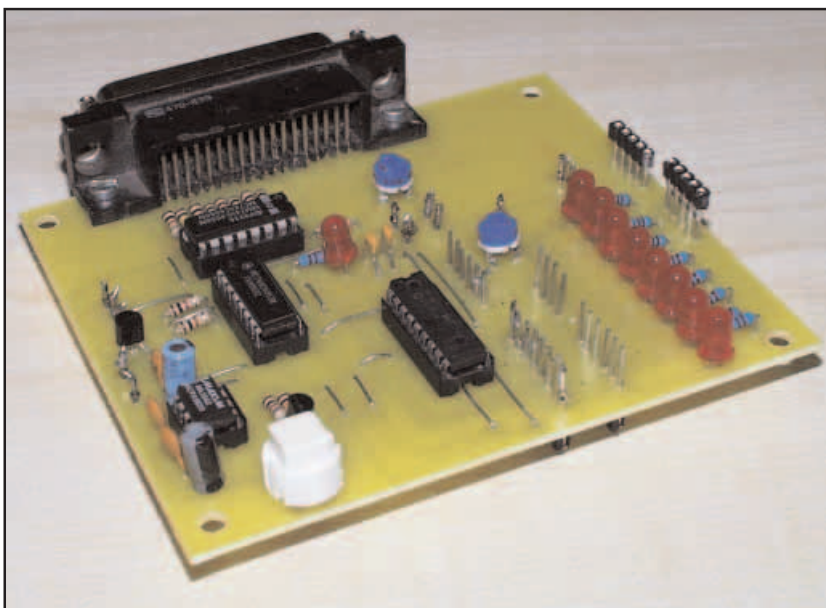
They could also be assembled on strip-board, for a more permanent construction, although guidance on stripboard assembly is not given.

PIC16F628

The PIC16F628 was chosen because it is a good compromise between the various PIC types available and simplicity of use. There are many PICs in the current range which are totally unsuited to learning about PICs in general, requiring too many concepts to be grasped by the newcomer to PICs.

The PIC16F628 is one of the 16F family but without a lot of the 'frills' now found in many PIC families. There are other 16Fs that could have been chosen, but this one is widely available from many suppliers. For this series, the PIC16F627 could also be used without changes, the only difference is that it has a somewhat smaller memory capacity.

Once you understand the basics of programming a PIC16F628, your knowledge



Prototype of the dual-purpose PIC programming and development interface board used in the Teach-In 2008 series

can be readily used to write programs for other PICs from the increasing number of types available. Most of the commands used are similar between types, although the method in which they are used can vary between PIC families.

Getting started

In this first part of the series we tell you about the general nature of a PIC microcontroller, and present a simple PIC programming circuit which is assembled on a small printed circuit board (PCB). Its controlling software is the author's renowned *Toolkit TK3* assembler/programmer. This provides the essential aspects required for writing and assembling PIC software, and programming the PIC with the results via a PC's parallel printer port.

There are many text notes built into the *TK3* program that give information on how use it.

The board is also used as the Master Control PCB for the *Teach In 2008* demonstration programs. It will also be of future use when writing your own software.

It is recognised that many modern PCs do not have a parallel printer port, and use a USB serial bus. For those readers who cannot use the programming aspects of the Master Control PCB to program their PICs, it is recommended that a simple PIC Programmer such as the PICKit2 programmer be used, as reviewed by Mike Hibbett in the July '07 issue.

PICKit2 can be used to actually program your PIC, and then the PIC can be transferred to the Master Control PCB for use in the demo program examples presented in this series.

The Master Control PCB is described later, along with its assembly. Details of obtaining the PICKit2 hardware and software are also given later.

If you already have the PCB designed to go with the *TK3* software when it was originally published, then you may use that instead of the Master Control PCB. The same applies to the *TK3* board available pre-built from Magenta Electronics.

The *TK3* boards have facilities for programming a variety of PIC sizes.

Origin

When the original *EPE PIC Tutorial* was published in March to May 1998, letters and phone calls to *EPE* had demonstrated that interest in Microchip's PIC microcontrollers had become intense. Many readers were asking for more information on how to use these devices in designs of their own invention.

In the words of one reader, "Please show me how to get to grips with the essence of PICs. Tell me, step-by-step, how to get started with writing simple programs, how to just turn on a single light emitting diode, for example. Then take me forward from there".

This *Teach In 2008* first takes the general concept of using a PIC to turn an LED on and off, and then progresses to show how this concept, and others which follow during the series, can be used in practical situations. At various stages of the series, additional commands and concepts are introduced as part of the demos, and they are explained in turn.

By the end of the series you will have a good grasp of all the commands available, and of how to implement the concepts presented in your own designs. Many thousands of readers have already learned to do this via the *PIC Tutorials* previously published.

We assume in this series that you have no previous knowledge of PICs and their programming, although you may find it useful if you know a bit about digital logic, but this is not essential. It is important that you have had some experience of electronic component assembly when it comes to copying and using the breadboard layouts, along with assembling the Master Control PCB.

What is a PIC?

It's worth explaining briefly what a PIC chip is, before we move ahead. A PIC chip, in this context, is a microcontroller integrated circuit manufactured by Microchip. When asked about the name's origin, Microchip's Technical Department replied, "PIC is not an acronym; it is just a trademarked name that General Instruments came up with a long time ago". (GI were the originators of PICs.)

A microcontroller is similar to a microprocessor, but it additionally contains its own program command code memory, data storage memory, bi-directional (input/output) ports and a clock oscillator. Many microprocessors require the use of additional chips to provide these requirements; microcontrollers are totally self-contained, although they usually need an external clock source, such as a crystal (but not the PIC16F628, which has its own internal source).

The great advantage of microcontrollers is that they can be programmed to perform many functions for which many other chips would normally be required. This not only makes for simplicity in electronic designs, but also allows some functions to be performed which could not be done using normal digital logic chips – ie circuits for which a microprocessor and peripheral devices would be required.

There are many types of microcontroller manufactured by various companies, including the AVR family from Atmel, but

for at least 10 years *EPE* has largely standardised on PICs, and many readers appreciate this emphasis.

Microchip are recognised as one of the largest manufacturers of microcontrollers.

PICs are manufactured and supplied 'empty'. That is, they are without program codes (commands) and cannot control a circuit until they have been provided with a program that tells them what to do. It is the task of the program writer (you) to tell them what that is. The commands are written in a specialised form of English, largely consisting of mnemonics, known as the 'source code'.

There are several methods by which the source code can be written, such as assembler, 'C' in numerous forms, and varieties of Basic. It is assembler we use here. It is a very simple programming dialect, and utilises Microchip's own commands without the sophistication of higher level dialects such as 'C'. (Discussion of the use of flowcharts is beyond the scope of this series.)

An assembly program (such as that supplied for this series, and the PICKit2 system referred to earlier) then translates (assembles or compiles) the source code commands into a numerical form that the PIC can understand – the 'program code'.

This code, which is normally stored on a file in hexadecimal, is then sent (loaded) in binary format to the PIC by electronic hardware, such as the PCB described later.

Inside the 16F628

The pinouts for the PIC16F628 are shown in Fig.1.1 It is an EEPROM (electrically erasable programmable read only memory) device, but perhaps more correctly described as a 'flash' device, hence the 'F' in its type number. This means that it can be rapidly reprogrammed as often as you wish (within the limits stated by Microchip – but these run into many thousands of reprogramming cycles and should not normally concern you).

Note that there are several sub-versions of individual PIC types, having suffixes such as -04, -10 and -20. The suffix indicates the maximum clock rate at which the chip can be used: 4MHz, 10MHz and

which may be used for I/O, but their use as I/O depends on some other functional choices of pin use, and that aspect is best ignored at this stage.

The PIC16F628 has several oscillator modes, ranging from an internal 4MHz clock or external crystal control at different speed ratings, through to various forms of resistance control. It is only the first that will be used in this series. The PIC's datasheet gives details of other oscillator types if you wish to know more once this series has ended.

Keying-in PIC source code

You must be able to use a word-processing program (text editor) in order to write your own PIC source code. This must produce a text file that is totally without formatting and printer commands. That is, it must be able to generate a pure ASCII text file (and to input one).

The *TK3* assembly/programming software available for this series and the Master Control PCB, allows access to a choice of text editors, ranging from DOS Edit to NotePad. You may also provide your own links to your own preferred text editor if you wish.

Personal ability

Throughout this series we shall examine the 35 basic PIC commands in a fair amount of detail. It is hoped that this will give you all the necessary information to enable you to conceive a design in which you can use a PIC16F628 to control whatever situation you wish, and to write the code that will let it do so.

There is, though, much more to writing PIC programs than you may at this stage fully appreciate. Knowledge about individual commands and the way in which they can be used is not enough in itself. Programming is a way of looking at the world in ways that other people may not recognise.

You must have the mental ability to see each programming situation as a step-by-step function, visualising and analysing in your mind exactly how it is that you need to specify the complete program flow. You have to write the sequence of events with the correct grammar, with the correct spelling and in the correct order. Undoubtedly, you will make mistakes while you are writing the code, failing to see the correct sequence of events and using incorrect command structures.

You require the ability to analyse what you have done wrong and to correct it. You are likely to be confronted with an overall task that may, on occasion, take you into several days or even weeks of dedicated concentration.

Readers have occasionally asked how they can be taught to think like a programmer. There is no easy way in which this can be taught. Some people have the ability, some do not. The best way to learn is by actually writing snippets of code and getting those to work, giving you the experience and confidence to progress to more complex situations.

Programming, to those who have the ability to see things 'as they are' and not 'how they seem to be', can become extremely addictive. You could find yourself compelled to get back to the keyboard

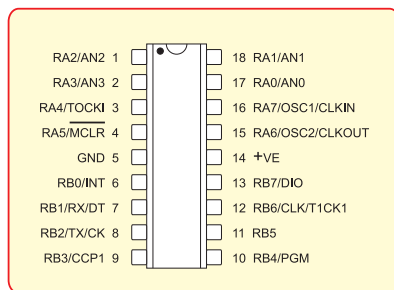


Fig.1.1 Pinouts for the PIC16F628

20MHz respectively. You may use any device speed rating for this *Teach-In* series.

The PIC16F628 used here has two input/output (I/O) ports, Port A and Port B. Port A basically has five pins (RA0 to RA4), and Port B has eight pins (RB0 to RB7). Port A does have three other pins,

and PIC programmer at any conceivable hour. You had better have an understanding family!

Readers who have had experience of programming in one of the general dialects of Basic, or with other types of microprocessor or microcontroller, will find that once a few commands have had their functions explained, using them will rapidly become instinctive. Other readers without such experience will, it has to be said, have to become accustomed to understanding programming itself as a step-by-step process. An analytical mind is required and, as said earlier, there is no easy way in which programming can be taught to those who lack experience.

Master Control Board

The circuit diagram for the Master Control board is shown in Fig. 1.2.

It is based on the circuit used by the author for the *TK3* board referred to earlier. It will not be discussed in depth. Details of the *TK3* board are available on the *PIC Resources* CD ROM, also referred to earlier.

The circuit can be run from a 9V to 12V DC power source, such as a battery or plugpack which plugs into household mains sockets. IC4 regulates the input voltage down to +5V, as required by the PIC and other ICs. IC1 boosts the +5V to around +14V to provide the programming voltage required by the PIC, and returning that voltage to +5V at the end of programming procedures.

MASTER CONTROL – DEVELOPMENT INTERFACE CIRCUIT

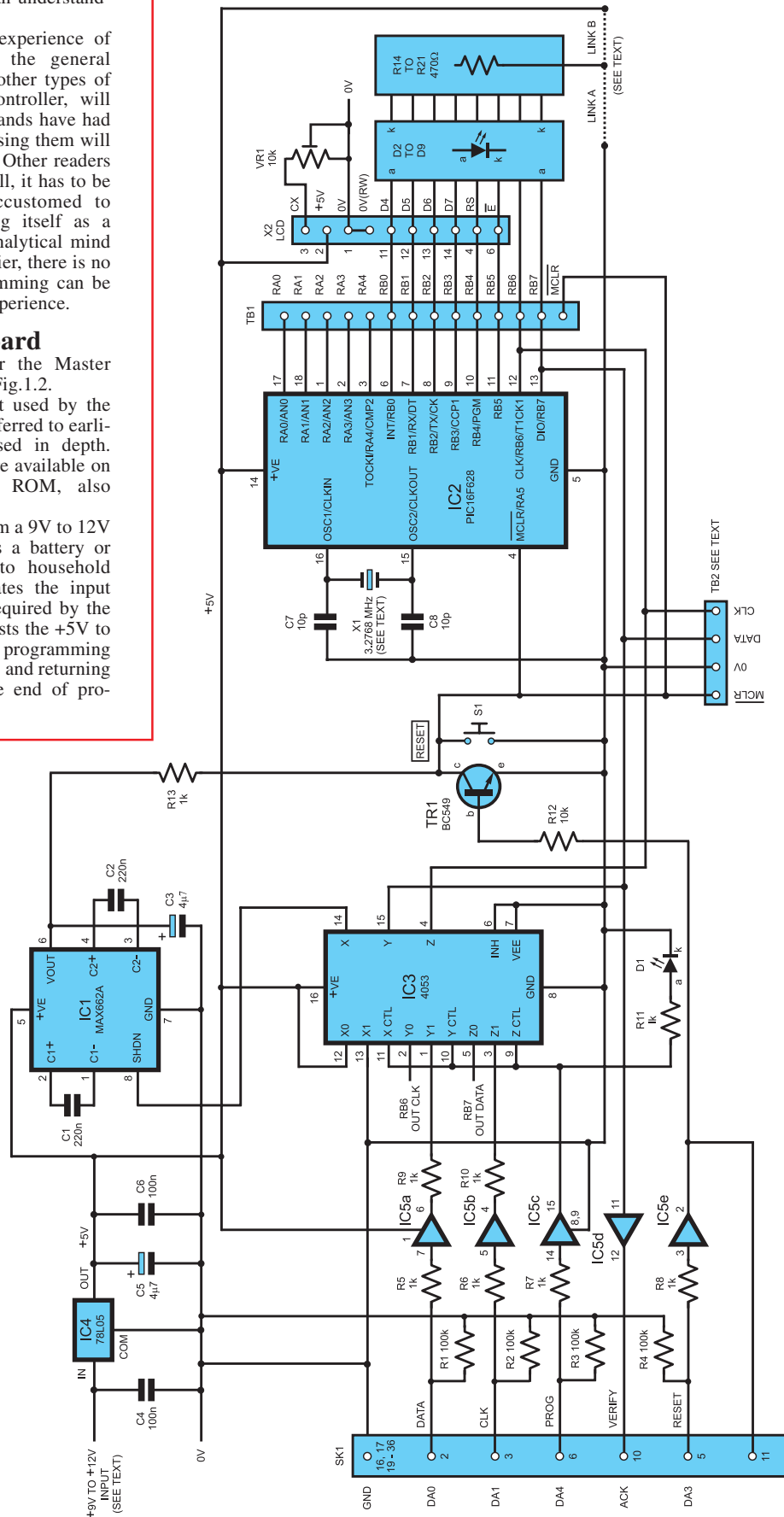


Fig. 1.2. Circuit diagram of the dual-purpose PIC programming and development interface (Master Control Board)

MASTER CONTROL BOARD

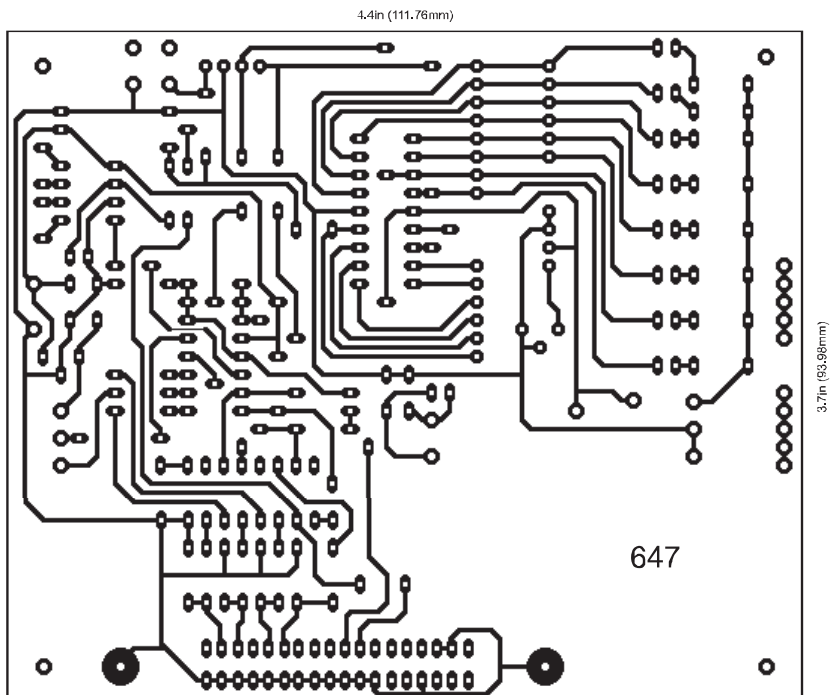
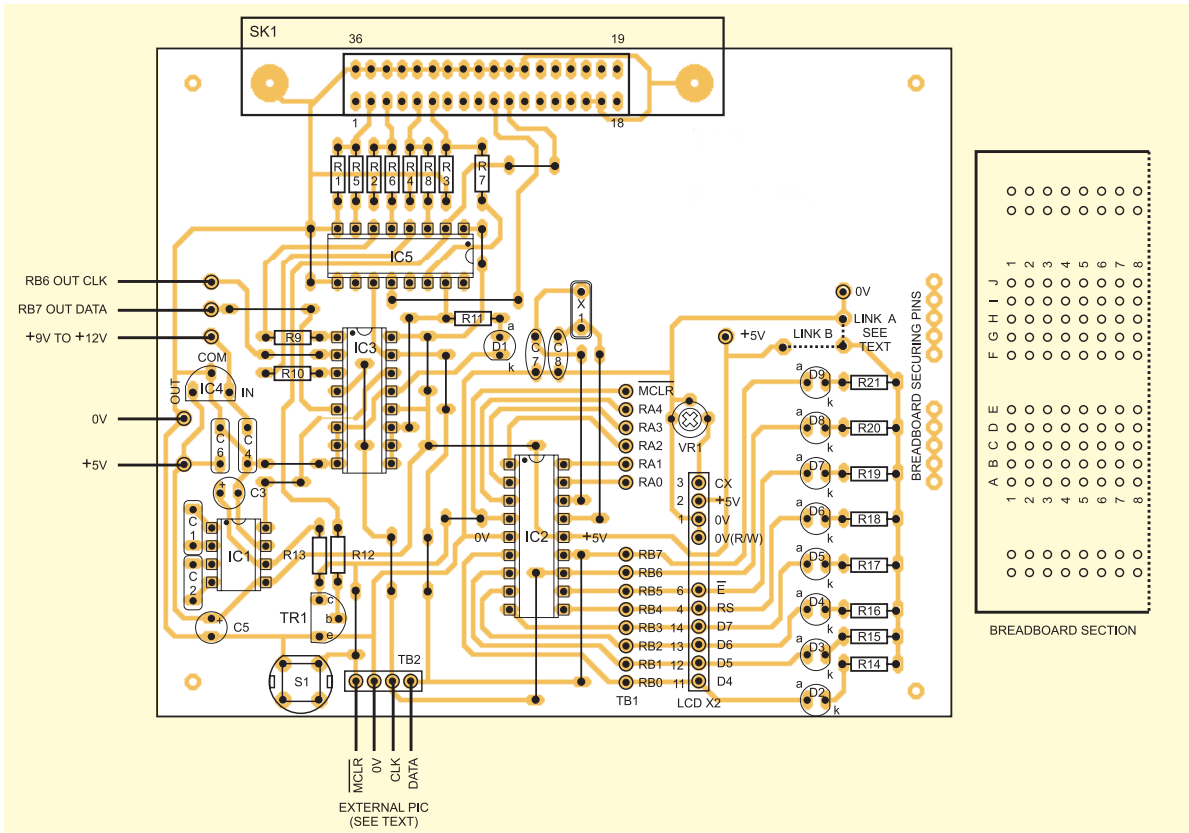


Fig.1.3. Assembly and track layout details for the circuit in Fig.1.2.

Programming control signals are provided by the parallel port of a PC (see earlier). The input signals, and those fed back to the PC during programming, are routed via IC5 and IC3 to the PIC, IC2.

PIC reset control is supplied by the PC and transistor TR1. Pushswitch S1 allows manual control of resetting when desired.

The connections at TB1 are those to and from the in-situ PIC's Port A and Port B I/O pins. Additional connections to Port B are provided for eight on-board LEDs. There is a link wire provided in the common cathode line, following buffer resistors R14 to R21, to connect the cathodes to 0V, so allowing the LEDs to be brought into service when required, and without affecting the Port B I/Os when they are not.

Link B may be used to reverse bias the LEDs if you wish to do so when they are not in use. **Never link both links.**

Additional connections (TB1) are provided on the PCB for connecting an alphanumeric liquid crystal display (LCD). Details for the LCD will be shown in a future part when its use will be discussed.

Also provided is a 4-pin connector point (TB2) through which other PICs on other boards can be programmed.

Master Control PCB assembly

Details of the track and component layouts for the PCB are shown in Fig.1.3. This board is available from the *EPE PCB Service*, code 647.

Note that the board has pin connections which can plug into a 0.1in pitch breadboard, as a convenient securing facility. A breadboard will be used throughout the series for assembling a few components for the various demonstrations.

Assemble the PCB in order of ascending component size, starting with the link wires, noting that some go under IC positions. Do not connect the link A or B wires to the right of the PCB – their use will be discussed with regard to LED usage in a future part.

Observe the correct orientation for all polarity sensitive components, including semiconductors and electrolytic capacitors.

Dual-in-line (DIL) IC sockets should be used for all ICs. The socket used for the PIC may be a zero insertion force (ZIF) socket for future convenience. When mounting socket SK1, securely bolt it to the PC before its connections are soldered.

Facilities for checking the assembled board functionally are provided by the *TK3* software, but do not insert any DIL ICs until the correctness of the voltage output by regulator IC4 has been proved to be +5V, within a few millivolts.

PC and PIC software

The *TK3* software for controlling the Master Control PCB, is available for free download from the *EPE* Downloads site, access via www.epemag.co.uk.

Simply save the zip file onto your PC and unzip the enclosed files into their named folder. They may be copied to a separate folder having a name of your choice. Do not attempt to 'install' any of the software via Internet Explorer or similar, use Window's own copying facility.

The PC software has been proved on Window's platforms up to and including

Parts List – Teach-In 2008 – Master Control PCB

1	PC board, code 647, available from the <i>EPE PCB Service</i> , size 112mm x 94mm	1	BC549 NPN transistor (TR1)
1	36-way Centronics parallel port connector, female (SK1)	1	MAX662A voltage converter (IC1)
1	3.2768MHz crystal (see text) (X1) (optional)	1	PIC16F628 PIC microcontroller (IC2)
1	9V DC power source, eg PP9 battery (see text)	1	4053 3-pole 2-way analogue changeover switch/multiplexer (IC3)
1	single-pole, PC mounting 'click-effect' pushbutton switch, push-to-make (S1)	1	78L05 +5V 100mA voltage regulator (IC4)
1	10kΩ miniature round preset potentiometer, PC mounting	1	4050 Hex buffer, non-inverting (IC5)
1	8-pin DIL socket	Capacitors	
2	16-pin DIL sockets	2	10pF ceramic disc, 0.2in pitch (C7,C8)
1	18-pin DIL socket	2	100nF ceramic disc, 0.2in pitch (C4,C6)
2	4-pin DIL 1mm pin-header strips (TB1 and TB2)	2	220nF ceramic disc, 0.2in pitch (C1,C2)
1	6-pin DIL 1mm pin-header strip (TB1)	2	4μ7 radial elect. 63V (C3, C5)
31	1mm terminal solder pins	Resistors (0.25W 5% carbon)	
4	PCB supports, self-adhesive	8	470Ω (R14 to R21)
Semiconductors		8	1k (R5 to R11, R13)
9	5mm red LEDs (D1 to D9)	1	10k (R12)
		4	100k (R1 to R4)

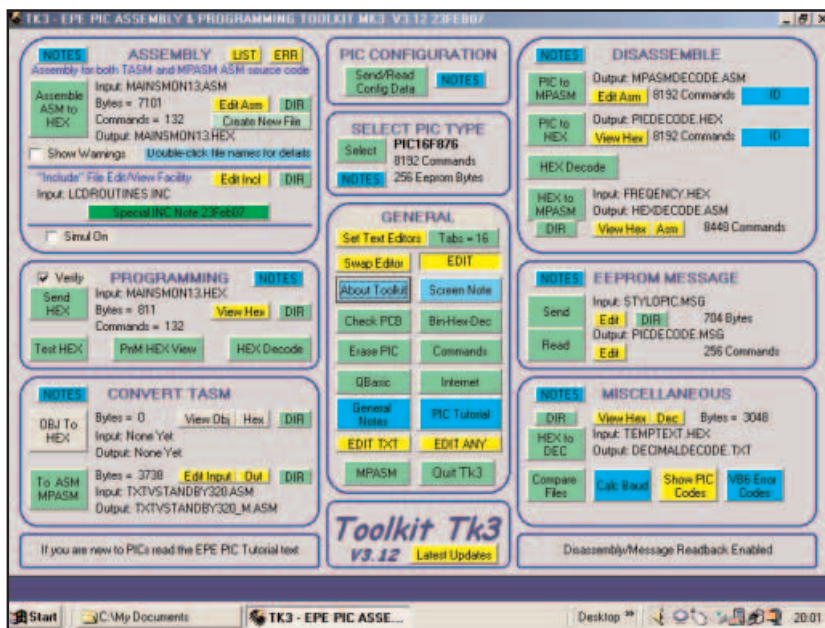


Fig.1.4. Main control screen of the *TK3* Programmer

XP, where such PCs have a parallel printer port included. The main control screen is shown in Fig.1.4.

There are numerous on-screen Notes click-buttons, which give access to various details about the PC software's use. It is not discussed here.

Basic PIC16F628 facts

All the commands for the PIC16F628 are shown in Table 1. Most of them apply to other PIC families too, though some

families also have additional commands available.

There are also some Special Register Files (SFRs) that are frequently used in PIC programs. Part of the PIC16F628's memory map is shown in Table 1.2. You normally work in Bank 0, but SFRs are held in other Banks, and you also have access to additional memory in some others too. Again, note that other PIC families may have somewhat different arrangements.

Table 1.1. PIC Command Codes For PIC16F62x

Command /Syntax	Flags affected	Cycles	Description
BYTE-ORIENTATED FILE REGISTER OPERATIONS			
ADDWF f,d	C, DC, Z	1	Add W and f
ANDWF f,d	Z	1	AND W with f
CLRF f	Z	1	Clear f
CLRWF -	Z	1	Clear W
COMF f,d	Z	1	Complement f
DECf f,d	Z	1	Decrement f
DECFSZ f,d	-	1 (2)	Decrement f, skip if 0
INCF f,d	Z	1	Increment f
INCFSZ f,d	-	1 (2)	Increment f, skip if 0
IORWF f,d	Z	1	Inclusive OR W with f
MOVF f,d	Z	1	Move f
MOVWF f	-	1	Move W to f
NOP	-	1	No operation
RLF f,d	C	1	Rotate left f through Carry
RRF f,d	C	1	Rotate right f through Carry
SUBWF f,d	C, DC, Z	1	Subtract W from f
SWAPF f,d	-	1	Swap nibbles in f
XORWF f,d	Z	1	Exclusive OR W with f
BIT-ORIENTATED REGISTER OPERATIONS			
BCF f,b	-	1	Bit clear f
BSF f,b	-	1	Bit set f
BTFSC f,b	-	1 (2)	Bit test f, skip if 0
BTFSS f,b	-	1 (2)	Bit test f, skip if 1
LITERAL AND CONTROL OPERATIONS			
ADDLW k	C, DC, Z	1	Add literal and W
ANDLW k	Z	1	AND literal with W
CALL k	-	2	Call subroutine
CLRWDt	TO, PD	1	Clear Watchdog Timer
GOTO k	-	2	Go to address
IORLW k	Z	1	Inclusive OR literal with W
MOVLW k	-	1	Move literal to W
RETFIE -	-	2	Return from interrupt
RETLW k	-	2	Return with literal in W
RETURN	-	2	Return from subroutine
SLEEP	TO, PD	1	Go into standby mode
SUBLW k	C, DC, Z	1	Subtract W from literal
XORLW k	Z	1	Exclusive OR literal with W

The full datasheets for various PICs can be downloaded free of charge from Microchip's website at www.microchip.com.

Before we start to look at programming PICs next month, there are a few facts to remember first.

Floating PIC pins

It is worth noting that PIC pins should never be left as 'floating' inputs. If any PIC pins remain unused in a PIC-controlled circuit, they should either be biased to one or other power line by individual resistors (say 10k to 100k), or set as outputs in a logic 0 (low) condition.

Case sensitivity

With some programmers (but not *TK3*), the names used in software are 'case-sensitive'. In other words, once you have allocated a name to a register, further use of the name must be in exactly the same style as the original with regard to the use of upper and lower case letters.

For example, names **STORE1** and **store1** cannot be used interchangeably.

However, the commands themselves (as opposed to the names) may be in upper or lower case without (usually) causing

Table 1.2 PIC16F628 Memory Map For The First Two Banks. (Microchip datasheet)

Indirect addr.(*)	00h	Indirect addr.(*)	80h
TMR0	01h	OPTION	81h
PCL	02h	PCL	82h
STATUS	03h	STATUS	83h
FSR	04h	FSR	84h
PORTA	05h	TRISA	85h
PORTB	06h	TRISB	86h
	07h		87h
	08h		88h
	09h		89h
PCLATH	0Ah	PCLATH	8Ah
INTCON	0Bh	INTCON	8Bh
PIR1	0Ch	PIE1	8Ch
	0Dh		8Dh
TMR1L	0Eh	PCON	8Eh
TMR1H	0Fh		8Fh
T1CON	10h		90h
TMR2	11h		91h
T2CON	12h	PR2	92h
	13h		93h
	14h		94h
CCPR1L	15h		95h
CCPR1H	16h		96h
CCP1CON	17h		97h
RCSTA	18h	TXSTA	98h
TXREG	19h	SPBRG	99h
RCREG	1Ah	EEDATA	9Ah
	1Bh	EEADR	9Bh
	1Ch	EECON1	9Ch
	1Dh	EECON2*	9Dh
	1Eh		9Eh
CMCON	1Fh	VRCON	9Fh
General Purpose Register 96 Bytes	20h	General Purpose Register 80 Bytes	A0h
			EFh
		accesses 70h-7Fh	F0h
	7Fh		FFh
Bank 0		Bank 1	

Teach-In 2008 Demos Parts 2 to 6 – You will Need

- 1 standard plug-in 'breadboard', 64 holes long by 14 holes wide, 1mm pitch
- 1 2-line 16-characters (per line) standard alphanumeric LCD
- 12 single-pole, PC mounting pushbutton switches, push-to-make
- 1 personal earpiece or miniature 40 ohm (approx) loudspeaker
- 1 10kΩ miniature round preset potentiometer, PC mounting

Semiconductors

- 14 5mm red LEDs
- 2 1N4148 signal diodes
- 1 BC549 NPN transistor

Resistors (0.2W 5% carbon)

- 7 470Ω
- 1 4k7
- 1 1k
- 4 10k

Some additional parts may be needed as the series progresses

problems. For example, in the *Teach In 2008* demo programs, the commands are usually shown in lower case, although they could have been in upper case.

True and false

In any logic question, there can only be one of two answers, either 'yes' or 'no' (you can never answer 'maybe' to such questions). In programming (and digital electronics too) if the answer is 'yes', then the answer is said to be 'true'. If the answer is 'no', then the answer is said to be 'false' (not true).

The convention is that if a situation is 'true' then it is represented by logic 1. Conversely, if the situation is 'false' it is represented by logic 0. Logic 1 and logic 0 are, of course, the two states in which a binary bit can be.

Set and clear

The concepts of the terms 'set' and 'clear', as frequently used in programming, are important to understand. In program terms, to 'set' a bit means to force it high, ie to logic 1; the term 'clear' is used to mean that a bit is forced low, ie to logic 0. Note, however, that in textual terms (ie in articles such as this) you are likely to come across the mixed use of the word 'set', in that you might be told to 'set a bit low'.

In such cases, the implied meaning should be obvious from the context. In this example, 'low' is the important word and 'force' or 'make' could have been used instead of 'set'.

STATUS register

Table 1.3 shows the arrange of the STATUS register, which is used for several purposes, depending on how its bits are set or cleared.

Bit 0 is the bit which indicates whether a Carry or a Borrow has occurred during some commands. It is, incidentally, common to refer to such bits as being 'flags': the flag is then said to be set or cleared by any action which affects it. The Carry bit is referred to as bit C.

Bit 1 is the Zero flag (Z bit), and indicates whether actioning a command has resulted in a value of 0 (Z = 0), or greater than 0 (Z = 1).

Other bits will be discussed as we progress.

F and W statements in commands

Data can be routed either to files or retained in the working register. A single code, either W or F, determines which destination is to be used. This code is required following the comma used with some commands.

For example, take the commands INCF PORTB,F and INCF PORTB,W. With the former, the value already held in PORTB is incremented and retained in PORTB, as instructed by the F. With the latter, the value already held in PORTB is incremented but retained in the working register, as instructed by the W, so no change is made to PORTB itself.

Program counter

Microcontrollers such as PICs keep track of which program byte number is currently being processed, and there is a counter which holds this information – the Program Counter (PCL, as it is named for the PIC, Program Counter Low). Unless told otherwise, when one instruction has been performed, the program counter is automatically incremented (a value of 1 added to it) and the next consecutive command is performed.

The program address number held by the PCL can be changed, either when the instruction is one such as GOTO or CALL, or by the user telling it to add another literal value to itself. The next instruction performed is that at the address pointed to by the new value. It will be seen, then, that if the value of 0 is added to the PCL, the next instruction is simply the next one on. If, however, the value of 1 is added to the PCL, then the

Table 1.3: Status Register (Microchip datasheet)

R/W-0	R/W-0	R/W-0	R-1	R-1	R/W-x	R/W-x	R/W-x	
IRP	RP1	RP0	TO	PD	Z	DC	C	
bit7								bit0
<div><div>R = Readable bit W = Writable bit U = Unimplemented bit, read as '0' -n = Value at POR reset -x = Unknown at POR reset</div></div>								
bit 7: IRP: Register Bank Select bit (used for indirect addressing) 1 = Bank 2, 3 (100h - 1FFh) 0 = Bank 0, 1 (00h - FFh)								
bit 6-5: RP1:RP0: Register Bank Select bits (used for direct addressing) 11 = Bank 3 (180h - 1FFh) 10 = Bank 2 (100h - 17Fh) 01 = Bank 1 (80h - FFh) 00 = Bank 0 (00h - 7Fh)								
bit 4: TO: Time-out bit 1 = After power-up, CLRWD instruction, or SLEEP instruction 0 = A WDT time-out occurred								
bit 3: PD: Power-down bit 1 = After power-up or by the CLRWD instruction 0 = By execution of the SLEEP instruction								
bit 2: Z: Zero bit 1 = The result of an arithmetic or logic operation is zero 0 = The result of an arithmetic or logic operation is not zero								
bit 1: DC: Digit carry/borrow bit (ADDWF, ADDLW, SUBLW, SUBWF instructions)(for borrow the polarity is reversed) 1 = A carry-out from the 4th low order bit of the result occurred 0 = No carry-out from the 4th low order bit of the result								
bit 0: C: Carry/borrow bit (ADDWF, ADDLW, SUBLW, SUBWF instructions) 1 = A carry-out from the most significant bit of the result occurred 0 = No carry-out from the most significant bit of the result occurred Note: For borrow the polarity is reversed. A subtraction is executed by adding the two's complement of the second operand. For rotate (RRF, RLF) instructions, this bit is loaded with either the high or low order bit of the source register.								

next consecutive instruction is bypassed (skipped) and the one beyond it is performed instead.

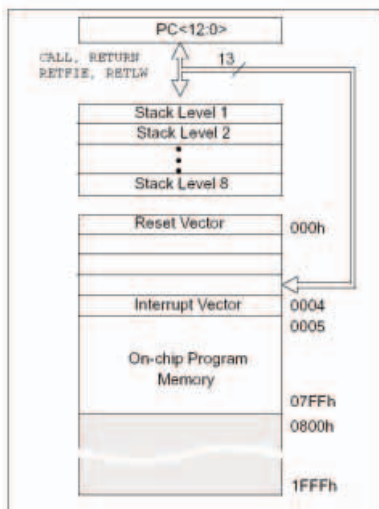
For example, if the program counter is at 52, then normally it will automatically add one to itself and the next instruction will be that at 53, and the one after that will be at 54, etc. If, somehow, we intervene and add 1 to the counter while it's still 52, then the counter will become 53 but will still add its own value of 1 to itself, making 54. The program will thus jump straight from 52 to 54, omitting the instruction at 53. Should the value of 0 be added, then, of course, the program will go straight from 52 to 53.

Opening ORG commands

In the opening statements of a PIC program, position ORG 0 is known as the reset vector (see Table 1.4). It is to this address that the PIC jumps when it is first run or subsequently reset. The command which follows it is then performed.

Position ORG 4 is known as the interrupt vector. It is to this address that the

Table 1.4: Program Memory Map And Stack For The PIC16F628



PIC program jumps if an interrupt occurs, then actioning the next command, whatever that may be, and there are several commands that could be used. The subject of interrupts will be dealt with later. Ignore the concept for the moment.

Position ORG 5 is the start of program vector, ie it indicates the first available position within the PIC at which the actual program can start.

You will notice that locations 1, 2 and 3 are not mentioned. These are reserved by the PIC and are not available for normal program use.

Having included the essential first few commands, everything else beyond ORG 5 is up to you.

Next month

In Part Two next month, we will start to describe how to program PICs by detailing the coding for a simple demonstration program that shows how just a single LED can be turned on or off, and then progress from there.



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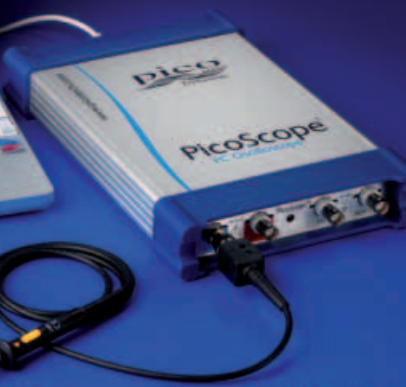
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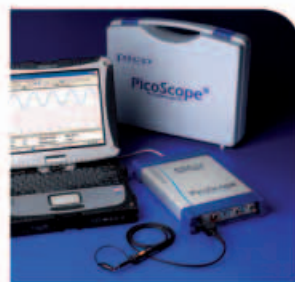
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IFA Electronics Show Berlin

Barry Fox reports that there were mixed feelings about the show and the products

The IFA electronics show in Berlin used to be held once every two years; now it is annual. Rudy Provoost, Head of Consumer Electronics at Philips, summed up the industry's reservations: "There are too many fairs and shows. It's too fragmented. In Germany we have Domotechnica, Photokina, CeBit, IFA. You can't dictate innovation by fairs. It must be very disappointing for consumers and journalists."

Perfect Pixel

Philips has now sold a million flat screens with Ambilight, the system which generates soft coloured ambient light which is controlled by the averaged picture content. The new Aurea 42-inch screen has an active translucent frame with 126 LED sources, each with red, green and blue components, firing to back and front. The bottom part of the ring has the Philips name in soft grey letters and when the ring lights up the name shows as jet dark black. Some viewers may find this very disconcerting.

The new Aurea set also used the latest version of Philips' image circuitry, which processes 249 million pixels per second to interpolate picture content and increase the display rate from 24/25/30/50/60 pictures per second to 96Hz or 100Hz, while eliminating judder on motion. The processor used to be called Pixel Plus but is now 'Perfect Pixel HD Engine'.

Philips head TV designer Danny Tack admits: "We are not using the name Pixel Plus any more. We had versions 1, 2 and 3. When I chose the name Perfect Pixel I thought, Oh, Oh, I am in trouble here. It's now perfect. We will keep the name for a while and then find a new name."

Sharp demonstrated the world's largest full HD LCD screen, a whopping 108 inches; at the other end of the scale Sharp also showed a prototype of the world's thinnest LCD panel – less than 30mm thick. So far there is no super-thin product to buy.

Hitachi unveiled the first camcorder which shoots HDTV direct to an 8cm Blu-ray disc. JVC has now bowed to the market pressure generated by the recent launch by Panasonic and Samsung of camcorders that shoot SD or HDTV direct to SD memory card; the latest Everio camcorders from JVC shoot either to hard disc or SD card.

Standards Battle

Most of the excitement in Berlin centered on the ongoing standards battle between Blu-ray and HD-DVD. Both sides presented statistics which showed their sales figures in the best light. The main bone of contention is whether sales of games consoles with HDTV movie playback should be included in total player sales figures. The Blu-ray Disc Group says Yes, because Sony has already sold 1.3 million PS3s in Europe, which gives it a claimed 94% share of BD-capable players in Europe; the HD-DVD Promotion Group says No, because Microsoft has done little to promote the HD-DVD add-on drives for its Xbox 360, and will not give any hard sales numbers for Europe.



Sharp thin screen LCD prototype

The HD-DVD Group cited independent figures, which showed the attachment rate for PS3 (number of movie discs sold for each player) as 0.5, or one disc for every two PS3s sold; the BD Group counters by saying that that BD is selling more than twice as many HDTV discs as HD-DVD in Europe. But the numbers are still very small; 534,000 BD movie discs against 231,000 HD-DVD.

The Blu-ray Disc Group had been rocked a few days before IFA by the shock announcement that Paramount and



JVC Everio Camcorder



Hitachi DZ-BD70E Blu-ray disc camcorder

DreamWorks had jumped ship and committed to exclusive releasing on HD-DVD. The trade rumoured that Toshiba had paid \$150 million to win exclusive support.

Said Danny Kaye, Fox Home Entertainment's executive vice president for technology and research: "Paramount said they wanted to support the format that gave the best proposition for the consumer, but they are now supporting the format that has the lower capacity, the least studio support, and the least hardware support."

Rudy Provoost, Philips Head of Consumer Electronics, laughed when asked if he had been surprised at the Paramount/DreamWorks jump ship: "In this business nothing is a surprise any more. But I certainly didn't expect Paramount's decision and I am still puzzled as to why."

Mixed Demonstration

To the surprise of the packed room, when the BD Group screened promotional

clips of HDTV movies from the Fox, MGM and Sony studios, they were of very poor quality. A BD Group spokesman later admitted that a 'series of screwups' had left the clips projected in Standard Definition quality, not HD!

The HD-DVD Promotion Group gave much more impressive demonstrations of HD picture quality but ducked all questions after Paramount's Chris Saito read an inconsequential statement on his ship jumping: "We decided HD-DVD was the best value for consumers and studios."

However, 'Mr DVD', Yoshihide Fujii, CEO of Toshiba's Digital Network Co, later admitted in personal talks that Toshiba had promised Paramount and DreamWorks 'some money' to cover costs 'to jointly promote' their titles. But talk of \$150 million was 'totally wrong', he insisted. "A studio would be stupid to accept money to back the wrong product."

"I love Sony," Fujii added. "I have a lot of friends there. I'm just sorry that Sony-

san made a very big mistake with Blu-ray." He then attacked the press for biased reporting of the format war. "It's just a stupid game," Fujii said. "Reporters don't tell consumers about the pros and cons of Blu-ray and HD-DVD. It's clear the mass media should support my idea."

Mr Fujii was then asked whether there was anything he did like about Blu-ray. 'Nothing!' he said vehemently. "Not a thing. HD-DVD beats Blu-ray in every single respect."

Attendance

IFA drew 235,000 domestic and international visitors to Berlin. The organisers are keen to stress that IFA is now an annual, international show that rivals January's CES in Las Vegas; out of 1,212 exhibitors from 32 countries, 733 companies, or 60 per cent, came from outside Germany. Countering rumours that IFA may return to its original biennial pattern, the organizers also claim an increase in the rented display area at the IFA 2007, by some twelve per cent.

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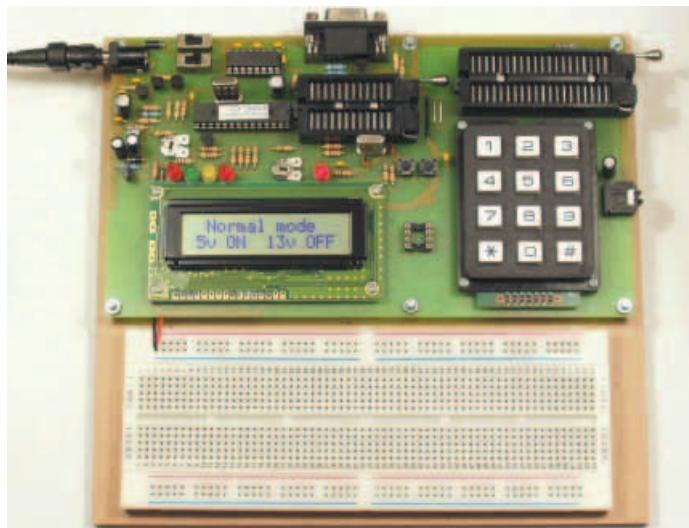
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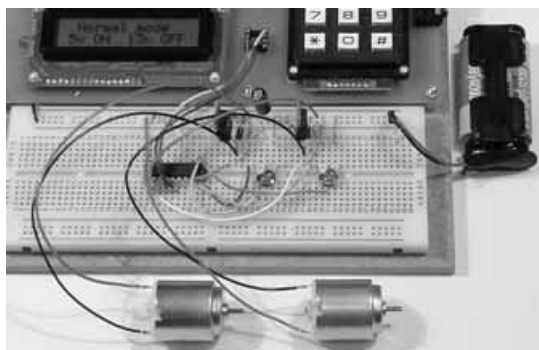
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Circuit Surgery

Ian Bell



Inductor Size and SPICE Simulation

We have received a question from **Godfrey (G4GLM)** prompted by a comment in an earlier article. In that article we were discussing the Royer converter, a circuit which is typically used to generate outputs of hundreds of volts from a low voltage DC supply. In recent times, Royer converters have been used for generating the high voltages needed for display back-lighting (using CCFL – Cold Cathode Fluorescent Lamps). Godfrey emailed:

I've an ignorant question, it's about something well known, but I've never seen it explained. Ian Bell refers to it briefly in Circuit Surgery June '07 'Higher frequencies enable smaller transformers to be used.' The 400Hz aircraft power transformers in my museum are certainly smaller than their 50Hz counterparts, indeed the reason for choosing this higher frequency for on-board generation is to allow for the smaller transformers and hence weight saving. So, why are they smaller? Attempting 50Hz on a 400Hz device leads to overheating!

It is generally true that using higher frequencies enables smaller transformers or other inductors to be used. The simple answer is that inductive reactance decreases at lower frequencies so if you apply a signal of the same voltage but lower frequency the current, and hence the power dissipation, will be higher. It follows that for a given voltage and current, the higher the frequency the smaller the inductance value you need. So by increasing the frequency you can use less inductance, which makes it possible to use a smaller transformer. In practice, there are some extra complexities, for example relating to the properties of the core material at different frequencies.

Putting a high frequency signal into a low frequency transformer, even at appropriate voltage levels, will probably not work very well. The low frequency transformer is likely to be highly inefficient at high frequencies and instead of transferring input power to the secondary windings it will tend to cause eddy currents in the core, which will heat up the transformer. High frequency transformers use core materials and winding topologies which optimize efficiency at the intended frequency of use.

As might be expected, the frequency/size relationship applies to inductors in general

and not just to transformers. This is an important issue for switched mode power supplies, which mainly use some form of inductor, but not always transformers. The last few years has seen a steady increase in the operating frequency of switched mode regulators. Prior to this, they (buck converters) all tended to operate at frequencies around 100kHz and typically used inductors of around 50 μ H.

The demand for reduced size in many electronic systems led IC manufacturers to design switching regulators operating at higher frequencies, allowing the inductor value and size to be reduced. For switched mode regulators at 1MHz the typical inductor value is 5 μ H, at 4MHz it is around 1 μ H and at 8MHz it reduces to around 0.5 μ H; at which point the inductor may be smaller than the regulator IC (figures from Micrel Semiconductors).

Using SPICE simulation

Computer simulation and other forms of Electronic Design Automation (EDA) are used extensively by professional electronics engineers. For hobbyists the most common forms of design software are probably for PCB layout and microcontroller programming. However, circuit simulators such as SPICE are used and occasionally produce discussion on the *EPE Chat Zone* forum (via www.epemag.co.uk).

For example, **atferrari** asks: *Using LT Spice, how could I simulate a repetitive signal with 12 levels between +2V and -2V?*

For the benefit of readers less familiar with simulation tools, we will provide a brief introduction before discussing the general issue raised by **atferrari**'s question. This boils down to: once you have drawn the schematic of the circuit, how do you go about setting up the actual simulation?

Your circuit alone is not enough – you have to define what happens on its inputs and outputs and also what kind of analysis to perform. We will be looking at some of the principles of using SPICE analogue circuit simulation which will be relevant with other SPICE simulators, not just LTSpice.

SPICE is an acronym for Simulation Program with Integrated Circuit Emphasis. It was originally developed in the early 1970s at the University of California, Berkeley (see <http://bwrc.eecs.berkeley.edu/Classes/IcBook/SPICE/> and <http://embedded.eecs.berkeley.edu/pubs/downloads/spice/index.htm>).

SPICE is still available from there (the latest version is spice3f5). SPICE is now a de-facto industrial standard for computer aided electronic circuit analysis with many commercial versions based on the work from Berkeley.

Although Spice was initially developed for analysing ICs, it can be applied to any electrical network (of resistors, capacitors, transistors etc). Spice was originally an analogue circuit simulator, but modern versions allow logic gates, and more complex digital functions to be included, allowing digital and mixed-signal (analogue and digital) circuits to be simulated. However, SPICE would not normally be used for large fully digital circuits.

Simulators

Integrated circuit designers use simulators because the high cost of manufacturing prototypes means that getting it 'right first time' is important – making changes to fabricated chips is very difficult or impossible. Commercial designs also have to work correctly every time when you are churning them out on a production line. This means that the design has to cope with variations in component values and manufacturing processes. Circuit simulators can provide designers with analysis of how these factors affect their designs.

These problems do not usually concern the hobbyist because they don't design ICs from scratch and usually only make one, or a small number of copies, of a circuit. If the circuit isn't quite right it can be trimmed and modded until it is. So is it worth using a simulator? That decision is up to you, but there are several advantages that make it worth considering. You can try out more challenging designs which you may not have confidence to commit to hardware without knowing they will probably work; you can quickly try 'what if' changes to a design which would be awkward with real hardware; you can make measurements to see what is going on inside your circuit which would be very difficult or impossible without very expensive equipment; and, of course, you can gain a deeper understanding of circuits and circuit design.

We have to remember that simulators are tools and that a good tool does not guarantee good results. The ways in which they are used and level of understanding of the user are often significant factors in achieving useful results. It is important to

realise that simulation is not design – it is a design aid, not a substitute for thinking.

Simulators can give the wrong answers in some circumstances, something which has led some people to have the opinion that they are not worth bothering with. Their extensive use in the electronics industry indicates this is not a widely held opinion, but, like any powerful tool, you will need to make some effort to learn how to make good use of it.

Buying design software can be tricky because there are often a large number of options. Companies often produce suites of tools and provide these individually or packaged in different combinations. Obviously, the more facilities in a particular option the more expensive it will be. There may also be a choice in terms of the software's performance, for example lower cost versions which are limited to smaller circuits. Low cost or free student editions are sometimes available, but you may only be able to get these with proof of student status. Best of all for the hobbyist on a tight budget is the fact that there are a number of free simulators available. The LTSpice simulator (also known as SwitcherCAD III) to which *atferrari* refers is one of these.

LTSpice

LTSpice is specifically designed for simulating switched mode power supplies; however, it also does a fine job with 'ordinary' Spice simulation tasks. LT produced the simulator because many other Spice simulators struggled with switch-mode circuits due to the complexity of the waveforms involved. It is available in its full form from the Linear Technology website,

www.linear.com/designtools/software/. It comes with a set of models of LT devices, particularly op amps (over 200 of them) and regulators, but other 'standard' Spice models will work with it if you have them available. There are quite a few LTSpice enthusiasts on line, so you can find helpful discussions and information.

To simulate a circuit you may need models of the basic components from which your circuit is built. A model tells the simulator how that component behaves, either in terms of mathematics or equivalent circuits. These may be provided for you as an external library supplied with the simulator, or they may simply be built into the simulator itself (eg basic resistors and capacitors in SPICE). Semiconductor manufacturers supply SPICE models for some of their ICs which can be added to supplied libraries.

Once you have models for all the components you can enter your design, usually by drawing a schematic on the screen, but text descriptions (called *netlists* in SPICE) can also be used. However, you have to enter more than just your basic schematic. For example, Fig.1 shows a simple op amp circuit, which is sufficient for showing what your design is, but not sufficient for simulation. A simulator is a bit like a virtual test bench. You need power supplies, signal sources and test equipment, as well as the circuit, if anything interesting is going to happen.

In Fig.2 is shown the circuit from Fig.1 with the extras added. V2 and V3 are two 5V voltage sources used to model the power supply. V1 is a voltage source that is being used as the simulation equivalent of a signal generator (or other signal source). R3 and C1 were added to provide a load for the circuit's output. Simulating the load may be critical to getting the right results; in other cases it will be less important.

The load components in Fig.2 are just an arbitrary example. In practice you will have

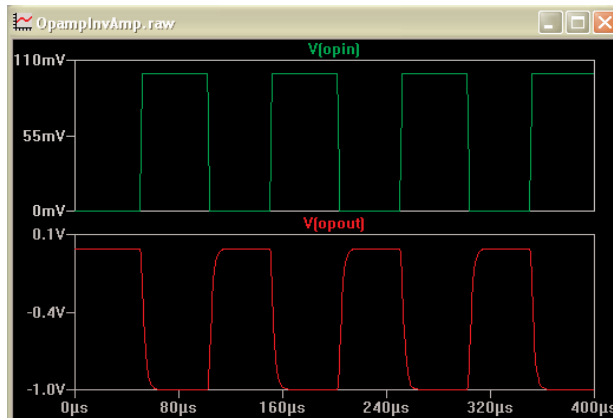


Fig.3. Example simulation results showing waveforms for the circuit in Fig.2

to configuring sources and we will return to this in more detail next month.

Analysis

Once you have entered your full circuit description you are ready to start simulating. SPICE simulators provide a number of analysis options, which in effect correspond to using different types of test equipment (multimeters, oscilloscopes, spectrum analysers, curve tracers etc) on the circuit. These analysis options include:

DC Analysis and Operating Point

Analysis: Calculates the behaviour of the circuit with only DC voltages and currents applied. This is usually performed (automatically) prior to other forms of analysis to determine bias conditions and operating points. This is like switching on the power, but not with the signal applied, and using a meter to measure the voltages (and currents) at test points in the circuit.

DC Sweep: Calculates a series of DC operating points (large signal transfer function). Like using a power supply to set a DC input and measuring the output (or other voltage) with a meter and repeating this for many input voltages.

Transient Analysis: Voltages and currents in the circuit are calculated as a function of time. Time-varying input signals must be applied to the circuit to obtain results different from a DC analysis. The results are usually displayed as a set of waveforms as you might see on an oscilloscope. Fig.3 shows a typical result from a transient analysis for the circuit in Fig.2.

AC Analysis: Also called *small signal analysis*. This calculates the behaviour of the circuit as a function of frequency. This is achieved by determining the DC operating point then analysing the network elements, under these conditions, as a function of frequency. This could be used, for example, to determine the frequency response of an amplifier.

DC Sensitivity Analysis: Computes changes in DC operating point due to component value variations.

Monte Carlo Analysis: Performs multiple analysis runs using statistical component value variations. If you are designing a circuit for mass production this will give you some idea of how much variation in circuit performance you will get between individual units.

Noise Analysis: Analyses noise levels in the circuit.

To be continued next month.

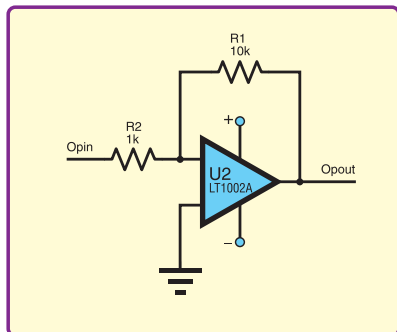


Fig.1. Circuit schematic in LTSpice – this is not sufficient for simulation

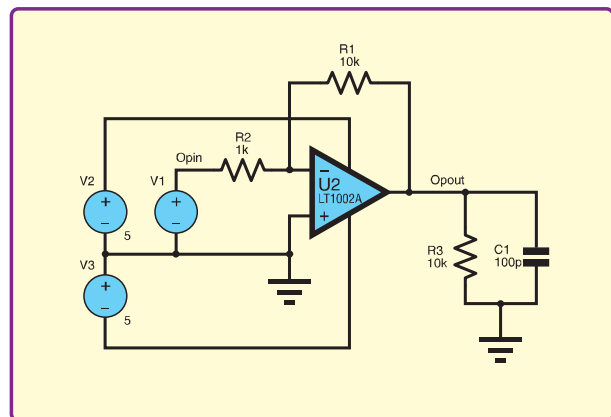


Fig.2. Schematic from Fig.1 with power supply, signal source and output load added. This circuit can be simulated

to know what your output is being connected to in order to decide on how to represent the load in the simulation. In general, the power supply, sources and loads may be modelled to varying degrees of accuracy or approximation, depending on how critical or sensitive the circuit is, and how much you know about the real environment the circuit will be in. Thus *atferrari*'s question is related

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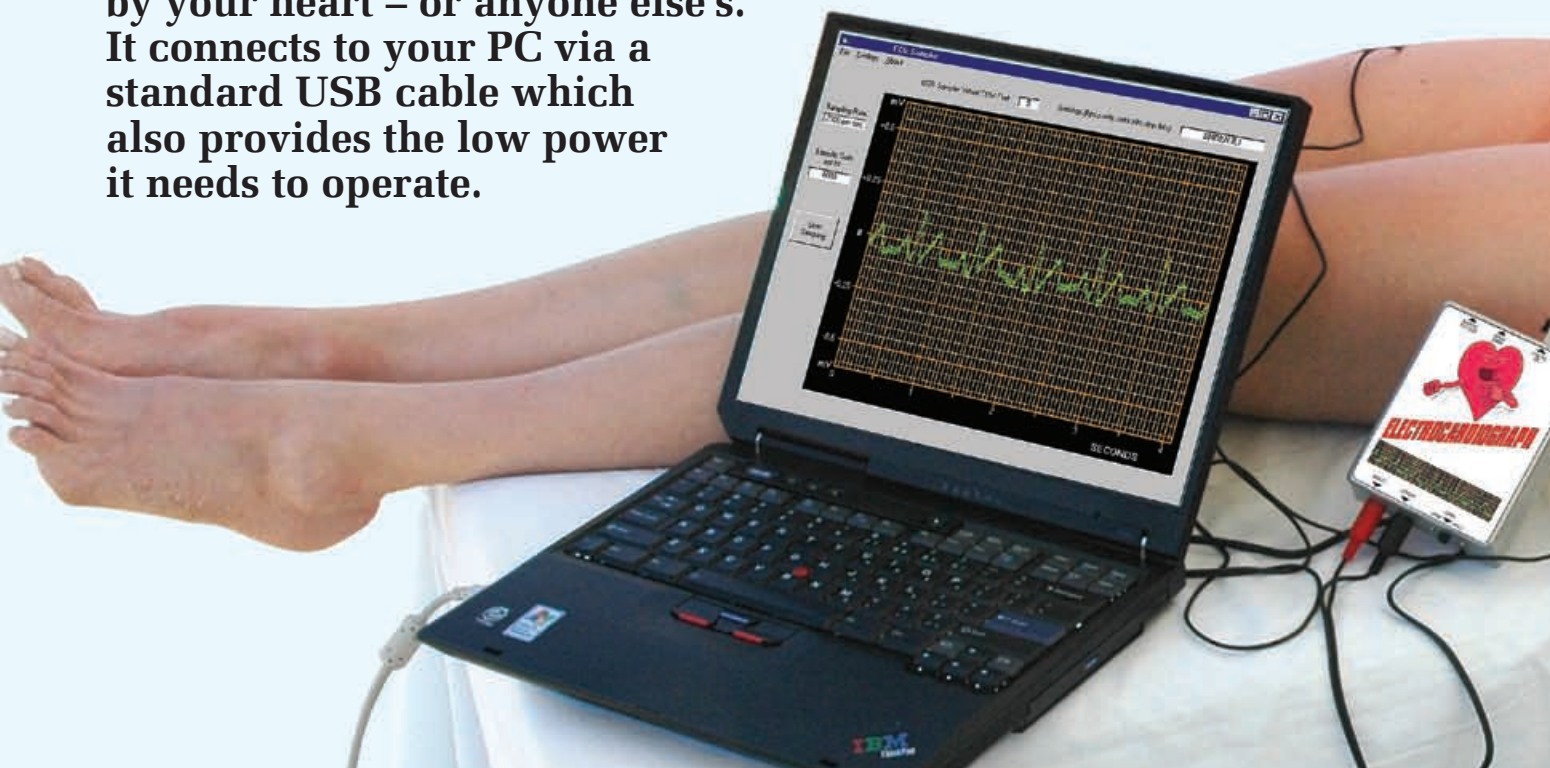


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Here's an easy-to-build project which will let you take your own electrocardiogram (ECG) and display it on a PC. You can read, display, save to disk and print the electrical waveform generated by your heart – or anyone else's.

It connects to your PC via a standard USB cable which also provides the low power it needs to operate.



An **Electrocardiograph** is a piece of medical equipment used to measure and record the voltages (ECG) produced as a result of heart muscle activity.

By attaching electrodes (or 'leads' as they are known in the trade) to the skin of your wrists, ankle or chest, our PC-driven ECG project can display, record or print out the same kind of ECG waveform on your personal computer.

Why would you want to build one? Well, looking at the waveforms generated by your heart can be both fun and educational.

You can monitor changes to your heart under various conditions, as your heart is affected by many factors such as emotion, mental and physical activity – even breathing.

All of these things have a demonstrable effect on the heart's ECG waveform.

Being able to show this easily, safely and at low cost is an added bonus.

Professional ECG machines can cost anything from £2000 up, and while this project is *not* intended to be used as a diagnostic device, the displayed, recorded and printed waveforms are of a quality approaching that of professional machines.

This PC-based electrocardiogram is smarter than previous models because its operation is under the control of an inbuilt PIC microcontroller. It's also faster and compatible with modern PCs, because it's linked to the PC via a standard USB cable – thanks to the use of an Elexol USBMOD3 interface module.

And finally it's easier to use, because all functions are controlled using a

Windows-based GUI program, written in Visual Basic.

Both the PIC microcontroller's firmware program and the Visual Basic PC program are available on the *EPE* website (www.epemag.co.uk).

The PIC program (ECGSAMPL.HEX) is in hex code form ready for PIC programming, while the VB program (ECGCONTR.ZIP) is in the form of a zipped-up installation package.

You'll also need a special USB virtual COM port driver which the PC needs to communicate with the ECG via a USB cable. This is also available on the *EPE* website, as R9052154.ZIP. Both the latter items can be installed directly on a PC running Win98SE or newer USB-compatible operating systems. Note that it won't work with Win NT-based systems – not through any shortcoming in the design, but the simple fact that NT doesn't recognise the USB port.

By JIM ROWE

CTROCCARDIOGRAPH



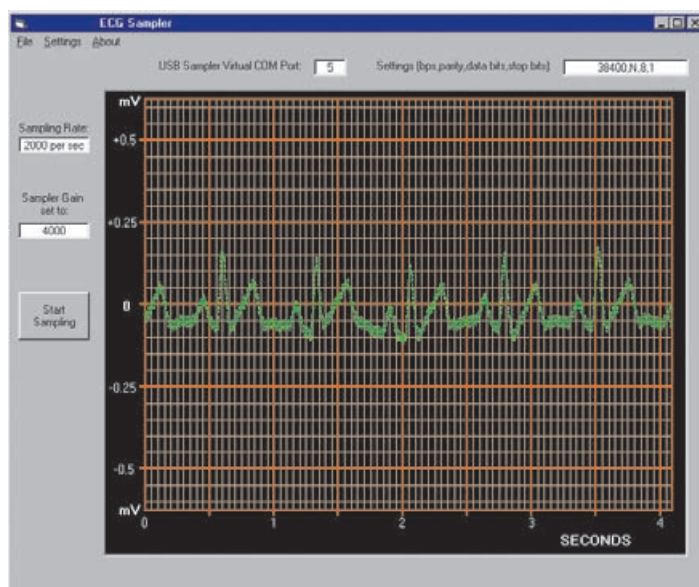
How it works

The muscles of your body are controlled by electrochemical impulses. These impulses are distributed to the muscles by the nervous system.

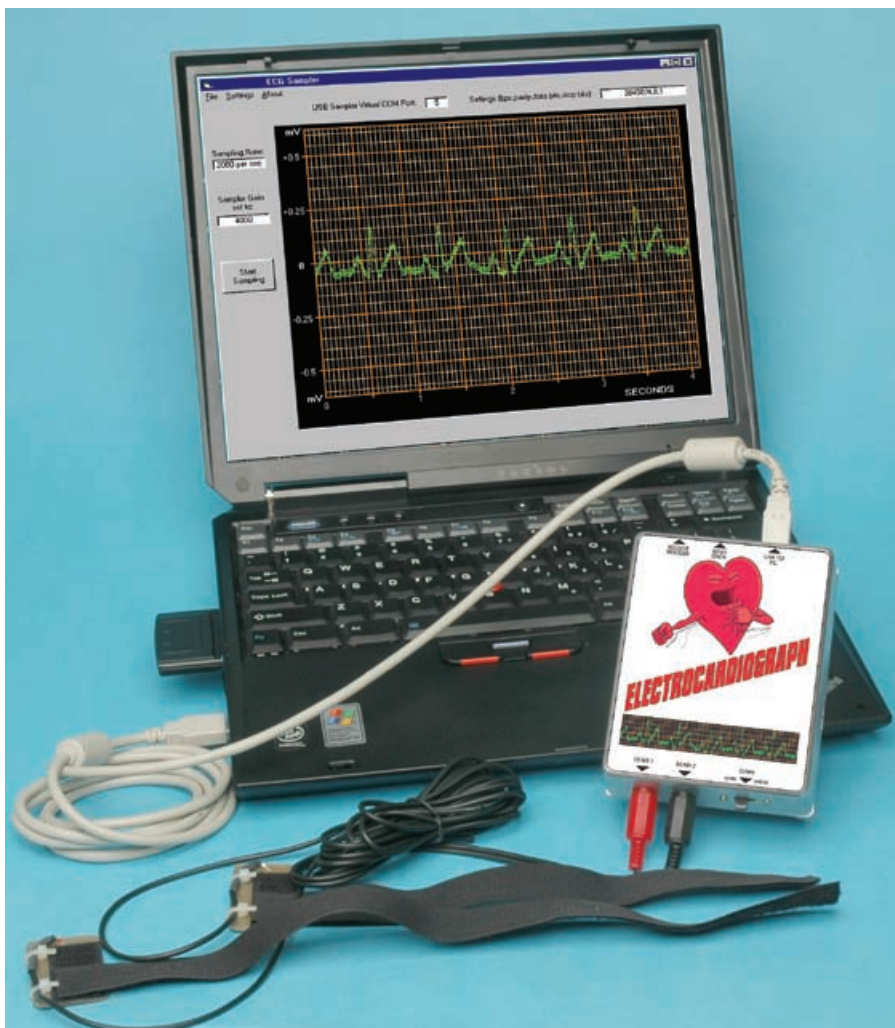
On reaching their destination, the nerve impulses cause the muscles to contract and produce much larger electrical voltages. A small proportion of these voltages is conducted out through to the surface of the skin where they can be detected using sensitive equipment, like an ECG (often also called EKG).

Because the heart is a large and rather complex group of muscles, which contract cyclically in a preset sequence (see sidebar panel), it is possible to study the overall condition of the heart by measuring the amplitude, timing and waveform of the heart muscle voltage components found on the skin. This is the reason for capturing ECG waveforms, which are obtained using two or more electrodes (pads) attached to the skin via conductive saline gels or paste.

Capturing ECG waveforms is really quite a challenge, because the voltage components found on the surface of the skin are quite small in amplitude: around 1mV peak-to-peak, depending on the positions of the electrodes



A 'screen grab' using this project on a live human. We make no comment on the condition of his/her heart from this graph: perhaps a cardiologist out there might care to?



The complete ECG setup using our Electrocardiograph, a laptop PC (with USB) and home-made electrodes. You can also use commercial ECG pads.

and the resistance between them and the skin. So to display or record these voltages we need to feed them through a high gain amplifier.

To make the job that much harder, the tiny voltages we want to measure are usually completely swamped by 50Hz hum, picked up by our bodies from the fields surrounding the AC wiring in our homes and offices, etc.

Luckily, we are only interested in the voltage differences between the two electrodes being used at any time, whereas the 50Hz hum picked up by the electrodes is virtually the same regardless of their position on the body. In other words, the 50Hz hum is a 'common mode' signal, while the tiny ECG voltages are 'differential mode' signals.

By using a highly balanced differential amplifier as the input stage of the ECG amplifier, we can cancel out most of the common-mode 50Hz hum before the differential ECG voltages are amplified.

By the way, the connections between the electrodes and your skin

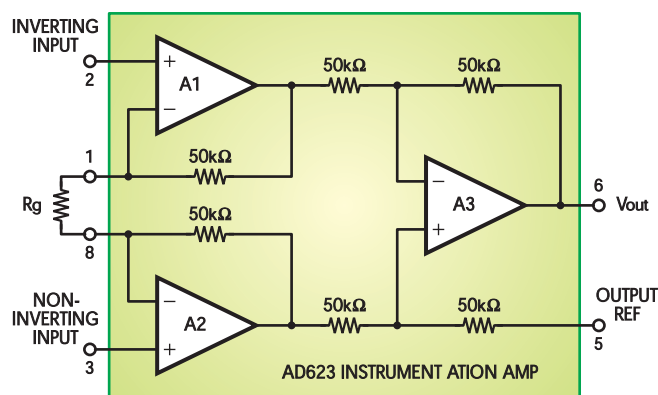


Fig.2: a simplified look inside the heart of the project, an Analog Devices AD623 instrumentation amplifier. It's essentially three op amps in one.

play an important role in this hum cancellation, because if one connection is poor this can upset the balance of the input amplifier.

Most of the remaining 50Hz signals are removed by low-pass filtering in the later stages of the amplifier. As a result, the output of the amplifier provides relatively clean amplified ECG signals, with very little 50Hz hum.

We then use a simple PIC-driven ADC (analogue-to-digital converter) to sample the amplified signals to be sent to the PC for display and recording.

Circuit description

Let's see how the circuit works. It is shown in Fig.1.

The shielded electrode leads are brought into the Electrocardiograph via connectors CON1 and CON2 and fed through 1μF coupling capacitors and series 3.9kΩ resistors to the inputs of IC1. This is an Analog Devices AD623AN device, a specialised instrumentation amplifier offering precision balanced differential inputs and hence very high common-mode signal rejection, combined with high gain.

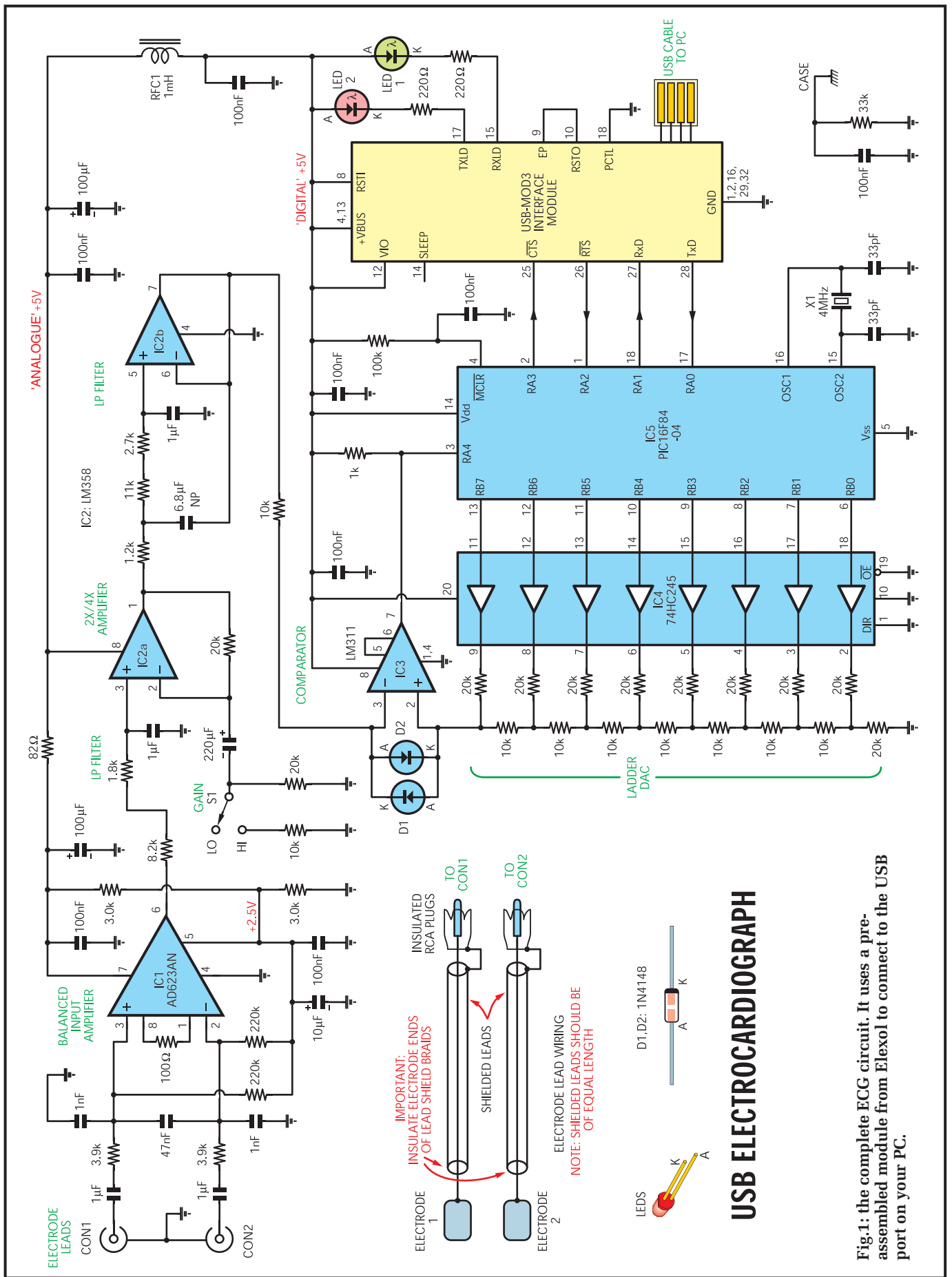
A simplified version of the circuitry inside the AD623 is shown in Fig.2. It is essentially three op amps in one: two matched-gain input stages feeding a balanced 'subtractor' output stage.

The overall AD623 gain for differential-mode signals is set by the single external resistor Rg (between pins 1 and 8), which gives a gain of 1000 times (60dB) using a value of 100Ω.

Returning to the main circuit, to ensure that IC1 can deliver maximum undistorted output level and also that the ADC used for sampling the amplified signals can handle the largest signal swing, we connect IC1's reference signal input (pin 5) to a low impedance source of +2.5V DC (ie, half the supply voltage).

This is provided by the voltage divider formed by the two 3.0kΩ resistors and it thereby sets the zero-signal output level of IC1 to +2.5V DC. The two 220kΩ input bias resistors for IC1 are also returned to the same +2.5V point, as you can see.

As IC1 is being operated with such a high gain, we also need to prevent it from amplifying any stray RF signals, which may be picked up by the electrode leads (or the subject's body). This is the purpose of the 1nF bypass



capacitors on each input of IC1 and also the 47nF capacitor between the two inputs. All three capacitors form a balanced low-pass filter, in conjunction with the two 3.9k Ω input series resistors.

The rest of the Electrocardiograph's amplifier and filter circuitry is based around IC2, an LM358 dual low-power op amp. The output from IC1 is fed to the input of IC2a via a passive RC low-pass filter formed by the series 8.2k Ω and 1.8k Ω resistors and the 1 μ F capacitor, which give a corner frequency (-3 dB point) of about 17Hz and an attenuation of about -9dB at 50Hz.

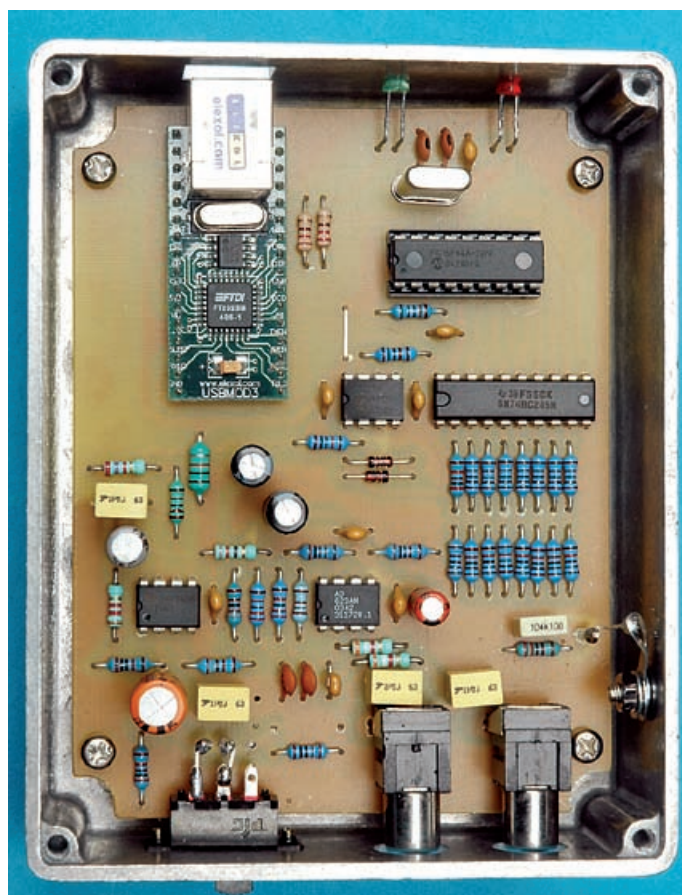
IC2a is used to give additional fixed amplification to the ECG signals, of either two or four times as set by switch S1, which determines the negative feedback ratio. So in the LO position of the switch the amplification in IC2a is 2, while in the HI position it gives a gain of 4. The overall ECG signal gain for the two switched positions is therefore 2000 and 4000 respectively.

IC2b is used to provide additional low-pass filtering, to further reduce any remaining 50Hz hum. With the R and C values shown this filter stage has a corner frequency of about 15Hz, providing further attenuation of about -21dB at 50Hz. At the same time it has unity gain for the low frequency ECG signals. So at the output of IC2b (pin 7) we end up with relatively clean and hum-free ECG signals, amplified by either 2000 or 4000 times depending on the setting of switch S1.

A/D conversion

The rest of the circuit is involved in performing analogue-to-digital conversion (ADC) of these signals, and sending them back to the PC via the USB cable and port. Both of these functions are controlled using IC5, a PIC16F84A microcontroller operating at 4MHz.

Analogue-to-digital conversion is done using comparator IC3 to compare the amplified ECG signals with a programmed reference voltage generated by IC5 and IC4, an octal transceiver containing eight digital buffers. IC4 drives the binary ladder network formed by the 10k Ω and 20k Ω resistors. The combination of IC4 and the ladder network forms a simple digital-to-analogue converter (DAC), whereby IC5 can generate any of 256 different



Looking straight down on the completed PC board, mounted inside the bottom of the case. Note the earth connection on the right-hand side of the box.

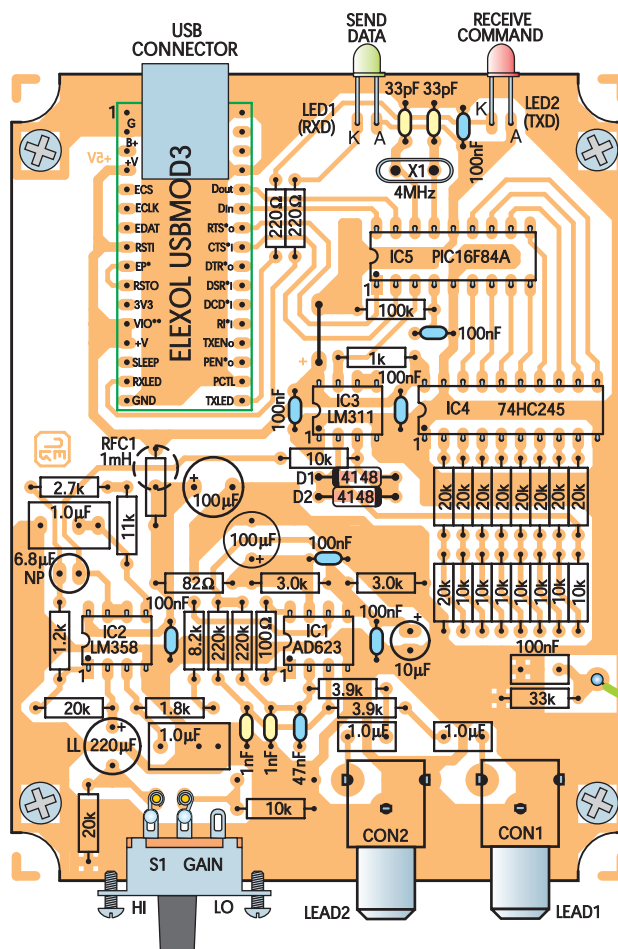


Fig.3: here's the matching overlay diagram to help you place the components correctly. Between this and the photo above, you should have no problems in construction.

voltage levels between 0V and 5V at the positive input (pin 2) of IC3, by providing 8-bit values on the outputs of its I/O port B (pins 6-13).

The output of comparator IC3 is connected to pin 3 of IC5, which is bit 4 of the micro's I/O port A, configured here as an input. This allows the micro to monitor the output of IC3 and perform a simple 'successive approximation' ADC algorithm. It generates a sequence of voltages at pin 2 of IC3 and changes the sequence according to the comparator output (which indicates whether the DAC voltage is higher or lower than the ECG voltage on pin 3). As a result, the micro can quickly 'zero in' on the ECG voltage during each sampling sequence, arriving at its 8-bit digital equivalent in only 48µs.

When each digital sample has been taken, the micro then sends it out in serial format (38,400bps) from bit 1 of its I/O port A1 (pin 18) to pin 27 (RxD) of the USB-MOD3 interface module. This module then reformats the sample and sends it back to the PC via the USB cable and port.

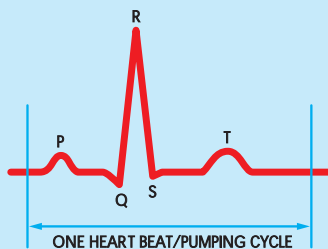
The micro is programmed in firmware to take a sequence of 8192 of these samples at a time, at any of three rates: 500, 1000 or 2000 per second. The rate is controlled by the Visual Basic software running in the PC, which sends a control code out to the micro when you click on the 'Start Sampling' button.

The control code is sent out via the USB cable, received by the USB-MOD3 module and then sent to the micro via the module's pin 28 (TxD), connected to bit 0 of the micro's I/O port A.

Two inverse-parallel connected diodes (D1 and D2) at the inputs of IC3 are used to limit the voltage swing between the comparator inputs to $\pm 0.6V$, regardless of the real difference between the amplified ECG and DAC reference voltages. This limiting prevents the comparator from being saturated and allows it to respond faster when the difference voltage changes in polarity.

The USB-MOD3 module is powered from the PC via the USB cable and it provides +5V DC from its +VBUS pins (pins 4 and 13), to power the rest of the circuitry. IC3, IC4 and IC5 are powered from it directly, while IC1, IC2 and the analogue circuitry are fed via a low-pass filter formed by RF choke RFC1 and the 100µF bypass capacitor. These remove any digital switching noise from the 'analogue' 5V rail.

Your Heart & Its Electrical Activity



Most people are aware that your heart is basically a pump, which pushes your blood around your body via your arteries and veins.

The typical human adult heart is about the size of a clenched fist, and weighs about 300 grams.

It is a popular misconception that the heart is located in the left side of the chest. It's not: the heart is located near the centre (although its apex points to the left) and is virtually surrounded above and at the sides by the lungs.

In a normal adult it pumps about once per second although this can vary dramatically due to a large number of causes (age, fitness, current activity and health/disease being just four).

The pumping action is triggered mainly by a nerve centre inside the heart, called the sino-atrial or 'SA' node. Each pumping cycle is initiated by a nerve impulse which starts at the SA node and spreads downwards through the heart via preset pathways.

The heart itself is made up of millions of bundles of microscopic

muscle cells, which contract when triggered. The muscle cells are electrically polarised, like tiny electrolytic capacitors (positive outside, negative inside), and as the trigger pulse from the SA node passes through them, they depolarise briefly and contract.

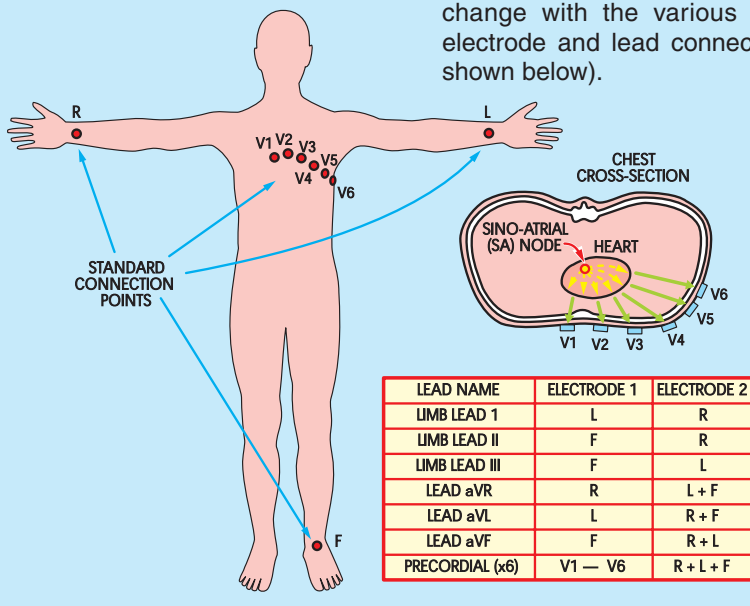
So with each beat of the heart, a 'wave' of depolarisation sweeps from the top of the heart to the bottom. Weak voltages produced by this wave appear on the outside surface of your skin, and can be picked up using electrodes strapped to your wrists, ankles and the front of your chest.

It's these voltages (about 1mV peak-to-peak) which are captured and recorded as an electrocardiogram or 'ECG'.

The actual shape and amplitude of the ECG waveform depends upon the individual being examined and the positioning of the electrodes but the general waveform is shown above.

The initial 'P' wave is due to the heart's atria (upper input chambers) depolarising, while the relatively larger and narrower 'QRS complex' section is due to the much stronger ventricles (lower output chambers) depolarising. Finally, the 'T' wave is due to repolarisation of the ventricles, ready for another cycle.

Doctors are able to evaluate a number of heart problems by measuring the timing of these wave components, and their relative heights. They can also diagnose problems by comparing the way the wave components change with the various standard electrode and lead connections (as shown below).





Here's the bottom of the case, which has become the top, showing the end cutouts for the electrode leads and the switch. Below right is the top of the case, which has become the bottom, showing the end LED and USB connector cutouts... Confused? All is explained in the text!

When it is transmitting or receiving data via the Tx/D or Rx/D lines, the USB-MOD3 interface module pulls down its TXLD (pin 17) or RXLD (pin 15) pins. LED1 and LED2 indicate bus activity.

Although the complete Electrocardiograph is housed in a metal box to provide shielding, the metal box is not connected directly to the signal earth as you might expect.

Instead, it's connected via a parallel combination of a 33k Ω resistor and a 100nF capacitor, to provide current limiting in the (unlikely) event of the earth connection of your PC becoming broken and the signal earth of your computer and the Electrocardiograph becoming 'live'.

Even if you are touching a good earth and the Electrocardiograph box at the same time in this situation, you should be safely protected from receiving anything more than a small 'tingle'.

Construction

All of the Electrocardiograph circuitry, except slider switch S1, is mounted on a PC board which measures 107 × 81mm and is coded 643.

The board assembly fits inside a standard diecast aluminium box measuring 119 × 93 × 34mm. The box is used upside down, with the PC board assembly mounted component-side down inside the main part of the box via four 6mm long M3 tapped Nylon

spacers, with eight 6mm long M3 machine screws (four of them with counter-sink heads, passing through matching holes in the box).

The two RCA phono connectors, used for the ECG electrode leads, are accessed through two 12mm diameter holes in one end of the box, with miniature slider switch S1 mounted in a 5 × 10mm rectangular hole at the same end, fixed in the case via two 6mm long M2 machine screws.

At the other end of the case are two 3.5mm holes for the indicator LEDs, plus a 13 × 11.5mm rectangular hole for access to the USB connector.

Assembling the components on the PC board is quite straightforward, as the only surface-mount parts used are in the Elexol USB-MOD3 module, which comes prebuilt and tested.

It's in the form of a 32-pin DIL package with machined pins on standard 0.6in × 0.1in spacing, which drop straight into matching holes on the main PC board and are then soldered.

To protect it from possible damage however, the module shouldn't be mounted on the board until you've fitted all of the other components. The component overlay diagram for the PC board is shown in Fig.3.

Board assembly

You can begin assembly by fitting the single wire link, which goes in the centre of the board just above the location for IC3. Then fit the PC pins: two for the connections to switch S1 and one for the 'earth' wire to the metal box itself.

Then fit the two board-mounting RCA connectors

CON1 and CON2. You may need to enlarge the slots in the board pads with a small jeweller's needle file, before the connector lugs will pass through them to allow the connectors to mount down against the top of the board. Then the lugs are soldered to the board copper underneath to hold them securely in place.

Next, fit the 18-pin IC socket for the PIC (IC5) which should be fitted with its notch end facing to the left, where the USB-MOD3 module will ultimately be fitted. Use a socket with machined pins, for higher reliability.

Fit the resistors next, taking care to fit each one to the board in its correct position as shown in the overlay diagram.

Then fit the multilayer monolithic and ceramic capacitors, again using the overlay diagram as a guide. The MKT capacitors and the 6.8 μ F non-polarised electrolytic capacitor and the 4MHz crystal can be installed either way around. The remaining electrolytic capacitors are polarised, so make sure that you fit these with the orientation shown in the overlay diagram.

Note that the 220 μ F electrolytic at the lower left corner of the PC board must be a low leakage type (RBLL).

The two 1N4148 diodes (D1 and D2) go in almost the exact centre of the board, with opposite polarities. Next, fit IC2, IC3 and IC4, all of which solder directly into the board. Make sure you fit them the correct way around, as shown in the overlay diagram. Then fit IC1, taking even more care, as it's rather more expensive.

The two LEDs are fitted next. Their leads are left straight, and introduced to the PC board holes with the longer anode leads towards the right (as seen



in the overlay diagram) and the 'flat' side of the LED bodies towards the left. The leads are then soldered to the pads under the board, with the LED bodies held directly above and about 15mm above the board. This allows them to be bent outwards by 90° afterwards, so the bodies will protrude out through the matching holes in the box.

Finally, you can drop the USB-MOD3 module into place and solder its pins to the pads underneath. You don't have to solder all of its pins; just those where the main PC board pad is connected to a track or the earth copper. These will be sufficient to make all necessary connections and hold the module securely in place.

Preparing the box

There aren't very many holes to cut in the aluminium box, but those there are should be located and cut accurately so that the PC board assembly and slider switch S1 will mount inside it without problems and the complete assembly can be connected easily to the ECG electrode leads and the USB cable. The location and size of all holes needed in the box are shown in the drilling diagram of Fig.4.

Final assembly

Use four countersink-head M3 screws to attach the four M3-tapped Nylon spacers to the inside of the box. Tighten these screws fairly tightly, because their heads become inaccessible when the dress front panel is attached later.

Now fit the PC board assembly into the box. You'll find it necessary to push the RCA connectors further through their box holes than their final position, to allow you to swing the USB module/LEDs end of the board down into the box. Once the board is sitting on the spacers you can slide the board back until its mounting holes are correctly aligned over the spacers. Then fit the four remaining M3 x 6mm screws, to attach the board assembly securely inside the box.

Once this is done you should be able to push the two indicator LEDs out through their matching 3.5mm holes, so they'll be visible when the box is closed.

The next step is to prepare the box 'earthing' connection.

This is done by passing a 9mm x M3 countersink-head machine screw through the single hole on the side of

Parts List – USB Electrocardiograph

- 1 PC board, code 643, available from the *EPE PCB Service*, size 107 x 81mm
- 1 diecast aluminium box, 119 x 93 x 34mm
- 1 Elexol USBMOD3 USB interface module (www.elexol.com), available from Active Robots (www.active-robots.com) in the UK
- 2 RCA (phono) sockets, PC board mounting (CON1,2)
- 1 1mH choke (RFC1)
- 1 4MHz crystal (X1)
- 1 miniature DPDT slider switch (S1)
- 1 18-pin DIL socket, with machined pins
- 2 6mm x M2 machine screws, round head
- 4 6mm x M3 tapped Nylon spacers
- 4 6mm x M3 machine screws, countersink head
- 4 6mm x M3 machine screws, round head
- 1 9mm x M3 machine screw, countersink head
- 1 M3 nut with two star lockwashers
- 1 solder lug
- 3 1mm PC pins

Semiconductors

- 1 AD623 instrumentation op amp (IC1)
- 1 LM358 dual op amp (IC2)
- 1 LM311 comparator (IC3)
- 1 74HC245 octal transceiver (IC4)
- 1 PIC16F84-04 microcontroller (IC5) programmed with ECGSAMPL.hex
- 1 3mm green LED (LED1)
- 1 3mm red LED (LED2)
- 2 1N4148 diodes (D1,D2)

Capacitors

- 1 220µF 50V RBLL low leakage electrolytic
- 2 100µF 16V PC electrolytic
- 1 10µF 16V PC electrolytic
- 1 6.8µF NP electrolytic
- 4 1µF MKT polyester
- 8 100nF multilayer monolithic
- 1 47nF multilayer monolithic
- 2 1nF NPO disc ceramic
- 2 33pF NPO disc ceramic

Resistors (0.25W 1% metal film)

- | | | | |
|---------|---------|---------|---------|
| 2 220kΩ | 1 100kΩ | 1 33kΩ | 11 20kΩ |
| 1 11kΩ | 9 10kΩ | 1 8.2kΩ | 2 3.9kΩ |
| 2 3.0kΩ | 1 2.7kΩ | 1 1.8kΩ | 1 1.2kΩ |
| 1 1kΩ | 2 220Ω | 1 100Ω | 1 82Ω |

For making two ECG electrodes:

- 2 insulated RCA plugs (1 red, 1 black)
- 3 metres of figure-8 shielded stereo cable
- 2 50 x 30mm rectangles of blank PC board (see text)
- 4 Nylon cable ties
- 2 40mm lengths of 20mm wide Velcro hook strip
- 2 350mm lengths of 20mm wide Velcro felt strip
- 2 25mm lengths of 4mm diameter heatshrink sleeving

the box, close to the terminal pin on that side of the mounted PC board. Then, to the inside of the screw, fit a star lockwasher, a solder lug, another star lockwasher and finally an M3 nut. The screw and nut should then be tightened up very firmly, so

the solder lug becomes a good and reliable electrical connection to the box metalwork. The lug is then connected to the nearby PC pin, using a short length of tinned copper wire or a resistor lead offcut. Make sure both ends are soldered properly.

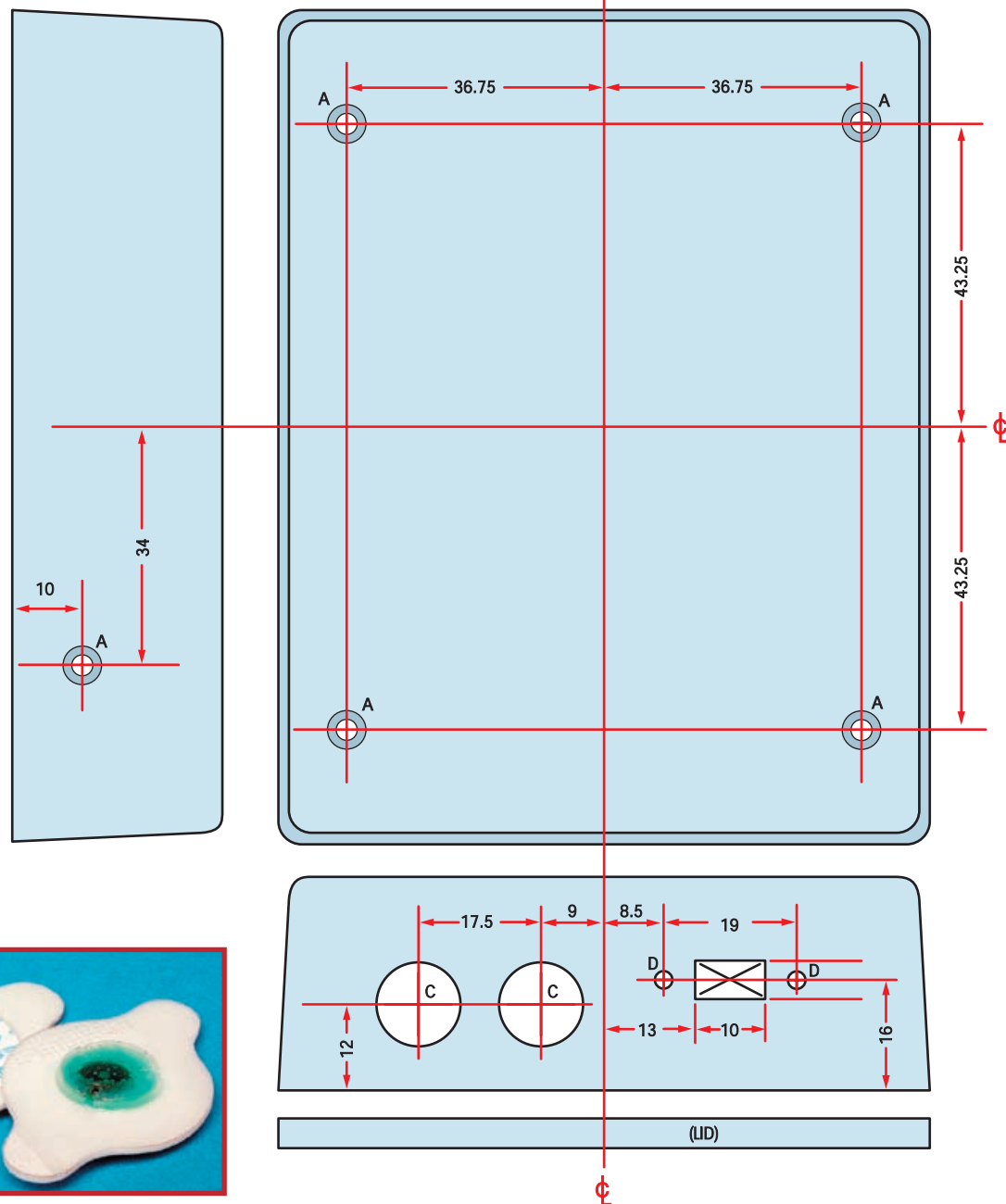
NOTE: ALL DIMENSIONS
IN MILLIMETRES

CASE OUTSIDE DIMENSIONS
92 x 119 x 35 INCLUDING LID

HOLE DETAILS:

- A: 3.5mm diam (CSK)
- B: 3.5mm diam
- C: 12mm diam
- D: 2.5mm diam

Fig.4: drilling details for the diecast aluminium box. The hole and cutout positions must be accurate to accommodate the PC board. Inset below: a pair of commercial ECG pads. These are self-adhesive and really, really stick!



Mount slider switch S1 in the end of the box, using two M2 x 6mm screws and connect the centre and leftmost switch lugs to the PC pins immediately behind them, using short lengths of tinned copper wire or resistor lead offcuts.

Now plug your programmed PIC micro IC5 carefully into its socket up near

the top of the board and then attach the box lid via the four screws provided.

The final step is to apply the front panel to the bottom of the box, which then becomes the top.

The artwork for the dress front panel is reproduced in this article, actual size (see Fig.5).

It can be photocopied onto a sheet of A4 self-adhesive label paper and then covered with clear 'Contact' or similar adhesive film, before being cut out along the outline border. Then the backing paper on the back of the label can be peeled off, allowing the dress panel to be stuck on the top of the

Electrocardiograph box. The adhesive film covering will protect the panel from finger grease and dirt.

You might also want to fit four small adhesive rubber feet to the lid/base of the box, so it won't scratch any surface it's placed on.

The electrodes: buy or make?

It goes without saying that the best electrodes you can use with this device are those intended for the purpose. Unlike the adhesive electrode pads made for TENS machines, ECG pads are disposable items and are therefore relatively cheap (only a pound or so each) but like TENS pads, are fairly difficult to find and usually have high minimum order quantities (eg, 50 minimum).

ECG pads are almost always removable from their leads – they usually use a press-snap type of fitting. If you can get them, we suggest you obtain pads with the male snap on them, as this gives you a convenient 'nipple' on which to clip a small alligator connector.

If you don't want to (or can't) buy pads, or find it inconvenient, there is an alternative 'pad' or electrode which you can make yourself. It's not as efficient nor convenient but once made, should last perhaps indefinitely.

It's made from a small rectangular piece of blank PC board. The details are shown in Fig.7.

Note that the shield braid wires of each lead are bent back away from the centre conductor and then insulated with a sleeve of 4mm OD heatshrink sleeving so they can't come into contact with either the centre wire or the human subject.

The centre wire is passed through the small hole in the electrode and soldered to the copper underneath, after which the end of the lead is firmly secured to the electrode using two small Nylon cable ties, each of which passes through one of the 3mm holes on the side.

As you can see from the circuit of Fig.1, the electrode leads are made from shielded microphone cable. The two leads should be of equal length, to maintain the balance of the ECG Electrocardiograph's input stage.

The home-made electrodes are held against the subject's skin with Velcro strips. A 40mm length of 20mm wide Velcro hook strip is attached to the top of each electrode using a small amount

of epoxy adhesive (eg, Araldite).

One end of a 350mm length of the matching felt strap is attached to one half of the hook strip. The strap can be run around the subject's forearm or ankle, pulled reasonably tight and then pressed into the 'other half' of the hook strip to hold the electrode in place.

It's very simple but it works surprisingly well. By the way, you need to make sure that the copper side of the electrodes is kept clean and bright, so it can form a good electrical contact with the skin.

Each time the electrodes are applied to a subject you also need to apply some conductive liquid or paste to both the electrode copper and the skin underneath – again to ensure a good contact. This normally applies to commercial pads too.

A convenient liquid to use is sodium chloride or saline solution, which is available at low cost from most pharmacists. Just wet a small piece of cotton wool with this and use it to apply a fairly generous amount to both the electrode and the subject's skin where it's being placed.

Installing the software

As mentioned earlier, there are two pieces of software which need to be installed on your PC before it will be able to communicate with and control the Electrocardiograph.

There's the Electrocardiograph control program itself, written in Visual Basic 6.

There's also a special 'USB virtual COM port driver' which allows Windows and the control program to communicate with the Electrocardiograph via its USB-MOD3 interface module and one of the PC's USB ports. The VCP driver has been written by the makers of the main USB interface controller chip in the Elexol USB-MOD3 module, an FT232BM device made by Scottish firm Future Technology Device International (FTDI).

A copy of FTDI's VCP driver is available for downloading on the *EPE* website (www.epemag.co.uk). It's also available directly from the FTDI website (www.ftdichip.com) and updated versions of it may be available there as well in the future. The actual driver file is included in the download file (R9052154.ZIP) which also contains a PDF document explaining how to install and configure it.

SAFETY WARNING

The circuit of this USB ECG is directly connected to the PC which controls it, via the USB cable.

Although no optical isolation is fitted, the electrodes which connect to the skin of the human subject are capacitively coupled and also have significant resistance connected in series with them.

This means that even if the PC's earth connection becomes broken and its power supply also develops a direct short circuit to active 230V AC (a very unlikely chain of events), the potential current which could flow through the body between the electrodes is very small and highly unlikely to cause injury.

If you are concerned about this small safety risk, there are two steps you can take to ensure that the USB/ECG project is used with virtually complete safety:

(1). Always ensure that the human subject to which the ECG electrodes are connected is insulated from earth and unable to contact any earthed (or 'live') metalwork.

(2). If insulation of the subject cannot be achieved, connect and use the USB ECG only with a laptop computer running from batteries – rather than a desktop or laptop PC running from 230V AC.

Basically, the procedure is to download the ZIP file and unpack it using Winzip or PKUnzip onto a suitable subdirectory on your PC's hard disk. Then when you first connect the hardware box up to your PC via a USB cable, and Windows comes up with its 'Found New Hardware Wizard' dialog box, you direct the wizard to the subdirectory where the driver package was unpacked, and tell it to refer to the file FTDIBUS.INF. It will then install the VCP driver for you.

After this is done it's a good idea to open up the Device Manager panel to set the port settings. The method is different for different versions of Windows. As we mentioned before, Windows NT is a no-go, as is Win95 (for the same reason).

Under Windows 98SE, open Control Panel (-> System Properties -> Device Manager), where you'll find a USB Serial Port device listed under USB High Speed Serial Converter. Select this port device, and click on Properties.

Then under the Port Settings tab select 38,400 bits per second, 8 data bits, None for parity, 1 stop bit and Xon/Xoff for flow control.

Finally, click on the Advanced button, and select COM5 as the port number. This forces the VCP driver to make its USB virtual COM port COM5, so there shouldn't be any clashes with any existing COM ports.

If you're using XP, go to Control Panel, -> System -> Hardware -> Device Manager, -> Ports (COM & LPT) where you should find the 'USB Serial Port' (probably set to COM4). Click on this and then 'Port Settings' and proceed as per Win98 (including the Advanced tab).

Now let's turn to the Visual Basic control program for the USB Electrocardiograph. This is available for downloading from the *EPE* website as a zipped-up installation package called ECGCONTR.ZIP. Inside this package are the CAB files for the program and its various support components and an installation program Setup.exe

together with its 'instruction sheet' SETUP.LST.

Download the package and unpack it on a TEMP directory. Then double-click on the Setup.exe file so that it installs everything to a suitable subdirectory of your Program Files directory. If you wish you can also create a shortcut on your Desktop, called *EPE ECG* or similar. The shortcut simply needs to be linked to the installed VB program itself, called ECGSampler.exe.

Taking an ECG

Apart from the gain – which is set to either LOW (2000) or HIGH (4000) using slider switch S1, all other functions of the Electrocardiograph are controlled using the ECGSampler program. This is very easy to use because when you fire it up it provides a GUI window (see screen grab) which allows you to set the configuration or to start taking an ECG recording and then display, save and print it.

There are three drop-down menus at the top, with the labels 'File', 'Settings' and 'About'. The first menu is for saving, reloading or printing ECG records, while the second is for changing various USB port and settings:

the virtual COM port, the COM port settings (bit rate, parity, stop bits etc.), the sampling rate (500, 1000 or 2000 samples/second) and also for advising the software on which position the gain switch has been set (Low/2000 or High/4000).

The third drop-down menu displays a small dialog box showing the version number of the software itself.

Once you have made sure that the software is set up correctly to suit the USB port and the Electrocardiograph, taking an ECG is then simply a matter of choosing which lead configuration you want, applying the electrodes to your subject (or yourself), and then clicking on the 'Start Sampling' button on the left-hand side of the GUI window.

A graphical 'progress bar' will then appear along the bottom of the GUI beneath the main display window, to show you the progress as the ECG samples are taken.

When all of the 8192 samples are received back from the Electrocardiograph, the progress bar will display again more briefly, as the ECG record is plotted in the display window.

The display window is calibrated in terms of both ECG voltage and time, as

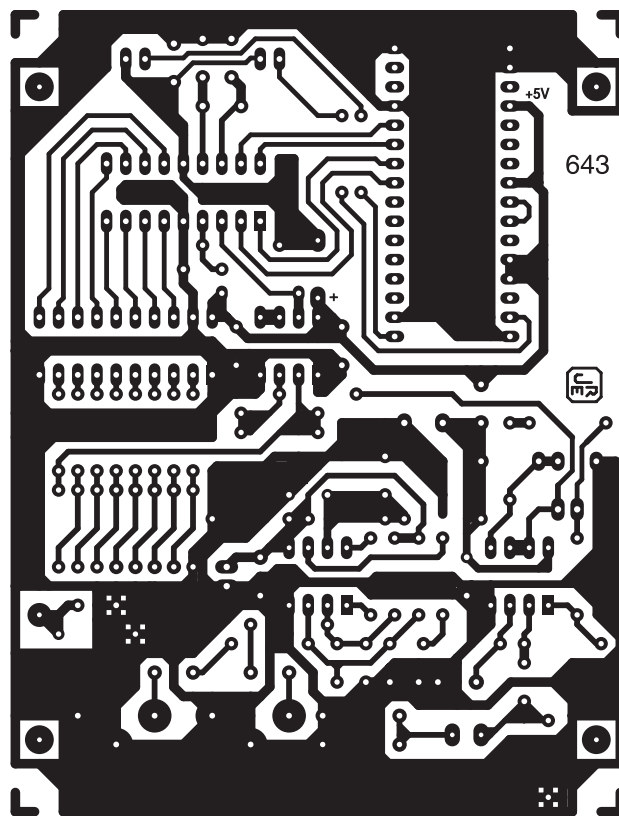
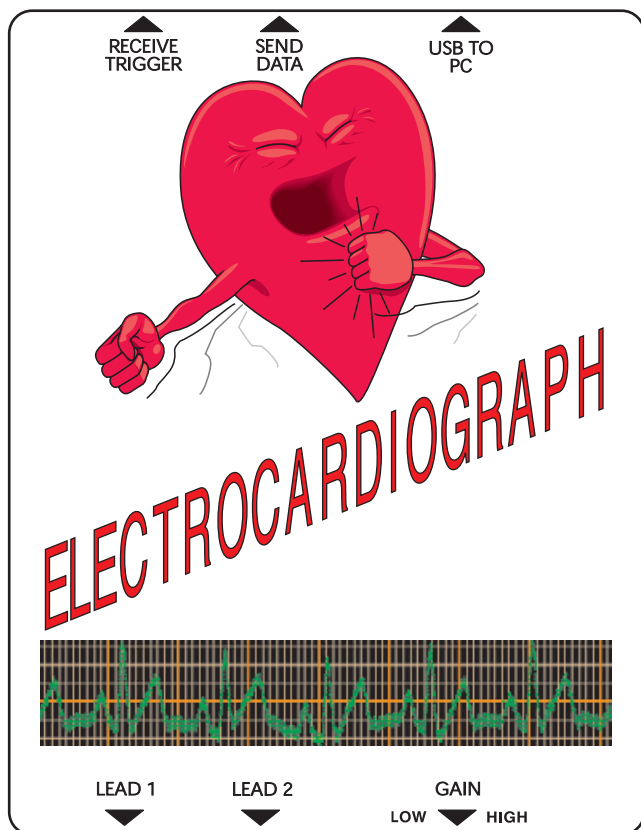


Fig.5: the full-size front panel, along with Fig.6, the PC board pattern (also full size).

shown in the screen grab. The same calibrations are reproduced when the record is printed out, along with the date and time – and when you save the record to your hard disk (or a floppy), the calibration info is saved with it as well.

So once you've taken an ECG record, it's easy to work out such things as the subject's current heart rate or other aspects of the ECG waveform.

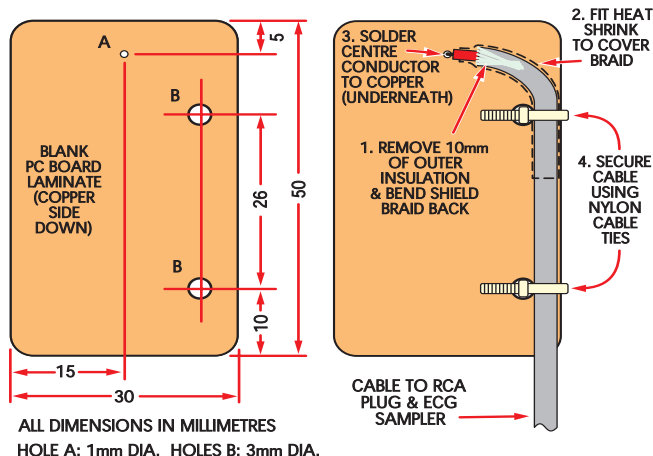
Lead configurations

Finally, which lead configuration should you use, just to take a basic look at your own ECG or that of someone else?

We suggest you use the 'Lead II' limb configuration, with lead 1 connected to the subject's left ankle and lead 2 connected to their right wrist or inside forearm. This usually gives the largest waveform amplitude, providing your electrode-skin connections are good. (See the diagram in the sidebar panel, *Your heart and its electrical activity*.)

If you get weak waveforms with a relatively large amount of hum, this is usually a sign of poor electrode contact. So take them off, apply a bit more sa-

Fig.7: if you want to make your own electrodes (pads) here's how to do it from a couple of scraps of PC board. The advantage – they're dirt cheap. The disadvantage: they get dirty (tarnished) very easily and need to be cleaned before use.



line solution and try again. The exact positioning of the limb electrodes is not critical, as the limbs are really being used as convenient 'conductors' joined to the four 'corners' of the subject's trunk. The main thing is to get the best possible contact to the skin.

If you want to try some of the chest positions for the lead 1 electrode, the electrode positions are then fairly critical. You really need medical knowledge to know the right chest electrode positions, so it's best to leave

these to the professionals. Note that when lead 1 is being used with a chest electrode, lead 2 should be connected to electrodes in all three of the limb positions so that it provides a 'whole body' reference signal.

So you'll need to make up at least two more electrodes, and connect these all in parallel – by connecting them to the Electrocardiograph's CON2 input socket via leads of the same length as the original two electrode leads.

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Using Flowcharts

For many of us hobbyists, or more accurately, for the majority of the microcontroller programs we hobbyists write, the code size is small enough that the process of developing the code is a straightforward task. We think about the overall design for a number of days, mulling it over in our heads, and then sit down and write code into an editor. It might take many days, but we hold the overall design in our heads and it slowly leaks out through the keyboard onto the screen.

Sometimes, however, we take on bigger or more complex projects, ones that can't be designed in our heads. Sometimes these projects can appear insurmountable, and we abandon them for other ideas. The problem is simply that 'designing in one's head' doesn't *scale* to larger problems. We need an alternative method, a technique that can cope with bigger and more complex projects.

Program planning tools

Fortunately for us, the professional software development community recognised this problem decades ago and has developed a number of techniques and tools to deal with it. Software tools (computer programs that assist us with writing programs) have been developed and are continuing to be refined and improved. It's a big business, with companies spending hundreds of thousands of pounds to buy tools to help their developers write software more effectively.

Not all of the 'software tools' are programs; many are techniques that can be used with pen and paper. Programs have been developed to simplify the process of using these techniques but are not essential. We will discuss some of these tools later on.

Flowcharting

One of the oldest techniques used by programmers is *flowcharting*, which uses simple drawings to show the flow of programs or subroutines. Flowcharts have found uses in many different areas, including manufacturing instructions, fault finding and business process descriptions. They are very good for showing *decisions* and *structure* in a program or subroutine.

Flowcharts consist of *symbols*, small pictures that represent a defined function. There is a small set of symbols to choose from and the symbols are easily understood which makes them ideal for explaining your program to other people, and to help you remember what you meant when you revisit the design at a later date.

The level of detail shown on a flowchart is entirely up to you. It can be very high level, perhaps showing the operation of an entire program on a single page, or very detailed, showing the intricate flow of a small section of code. Typically, you would generate a number of different diagrams starting at a high level and drawing diagrams for parts of the program that you feel are complicated enough to benefit from being shown on a diagram. This process of using a technique like flowcharting on parts of your program design is what is known as *analysis*, exploring and refining your ideas before committing them to actual code. For larger programs it's an essential step.

Flowcharting was invented in 1946 by John Von Neumann, the father of modern computer theory. By 1985 the symbols available for use had been formalised in a world wide industry standard called ISO5807. There are a number of variations in the type of symbols that are used across different business areas, but for modern day microcontroller software development a very small, simple subset of symbols can be used to express software designs.

Popularity

Flowcharts were a popular design tool up until the early 1990s. Until then it was possible to buy flowcharting stencils in the UK from high street stores like WHSmith. On a recent shopping trip to see if they were still available, the author was met by a blank stare to the request for design stencils, and eventually pointed in the direction of a home decorating store. How times have changed. Flowcharts have recently become so unpopular that they have even been ridiculed by some popular IT websites. It's quite ironic considering that the current 'hot' design language, UML, uses diagrams that are simply extensions of flowcharting symbols. Von Neumann was no fool, and his ideas persist today, if glossed up a little in tools like UML.

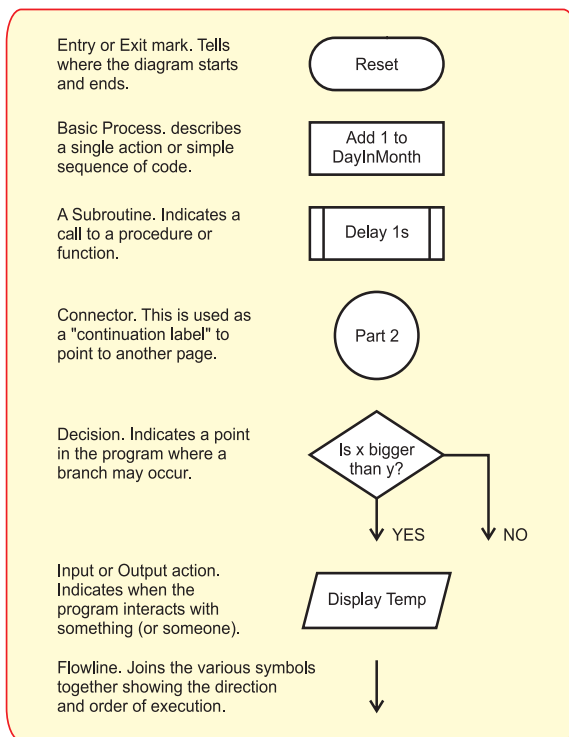


Fig 1: Flowchart symbols

Flowcharts are simple, easy to draw, easy to understand and offer a very useful way to explore different program designs without having to think about the nuances of the programming language you intend to use. Flowcharts don't assume that you will use any particular language and are, in fact, language neutral – you can convert a flowchart into any programming language you like, as will become clear shortly. They are, however, of particular use when using assembly language because so much of the structure of your program can get lost in the long lists of assembler instructions.

While the 1985 standard for flowcharting describes a large number of diagrams, many of these have only a historic value and can be ignored for modern day use. For us, writing programs for small microcontroller systems, the set of useful symbols is very small, and are shown in Fig.1.

With just those seven simple symbols on one or more diagrams you can accurately describe and design your program. Anything you can write in assembly code or a high level language like BASIC or C can be accurately represented in one or more flowcharts using those six basic symbols and the flow line.

Using flowcharts encourages a 'top down' approach to designing software because you start with a top-level view of your design and gradually build up the detail with additional diagrams. This is quite a sensible approach to writing programs when only one person (you!) is involved in the process. Commercial software development, involving many engineers, requires a more complicated 'component' based approach, where a great deal of effort goes into splitting a design into independent sections that can be developed concurrently – one of the reasons why flowcharting has lost favour in professional environments. For the hobbyist, however, the 'top down' approach using flowcharts remains a valuable way of developing those more challenging projects.

Drawing flowcharts

So how do we draw flowcharts? Being such simple symbols they are easy to draw using pen and paper, for even the most artistically challenged of us. There are, however, many drawing programs available that can simplify the process, from simple drawing tools to programs that will actually create full source code automatically. Some of these programs are free to download from the Internet, and we will discuss one of these later. First, let's explore *how* to use them.

Let's look at how the flowcharting symbols relate to a real program. Each flowchart starts with either an **Entry** symbol or a **Connector**. The Entry symbol represents, unsurprisingly, the beginning of a program or subroutine. Typically this would be equivalent to a label in your code at the beginning of the reset routine or subroutine. The Connector is simply a page continuation marker – you use this when your flowchart 'spills over' from one page to another. Try to use the Connector sparingly, since it can make flowcharts difficult to read.

The **Basic Process** is used to represent a short section of code, something that doesn't have any complicated loops or branches. Inside the picture of the symbol you would write a short explanation of what that section of code does. The level of detail that you write depends on the level of detail you are trying to express on the particular diagram. For a high level diagram you might write 'Increment date by one day', in a more detailed diagram this might expand to several symbols, one of which might say 'Add 1 to DayOfWeek'.

Always keep the level of detail on a diagram consistent: when you are drawing a high level diagram, avoid the temptation to drill into more detail when you start drawing a part of the program you understand better than others. Leave that for the next, more detailed diagram. Mixing levels of detail on a diagram is one of the more typical errors made when learning how to write flowcharts.

The **Subroutine** symbol is used to indicate a call to a subroutine, exactly equivalent to the 'call' instruction in assembler.

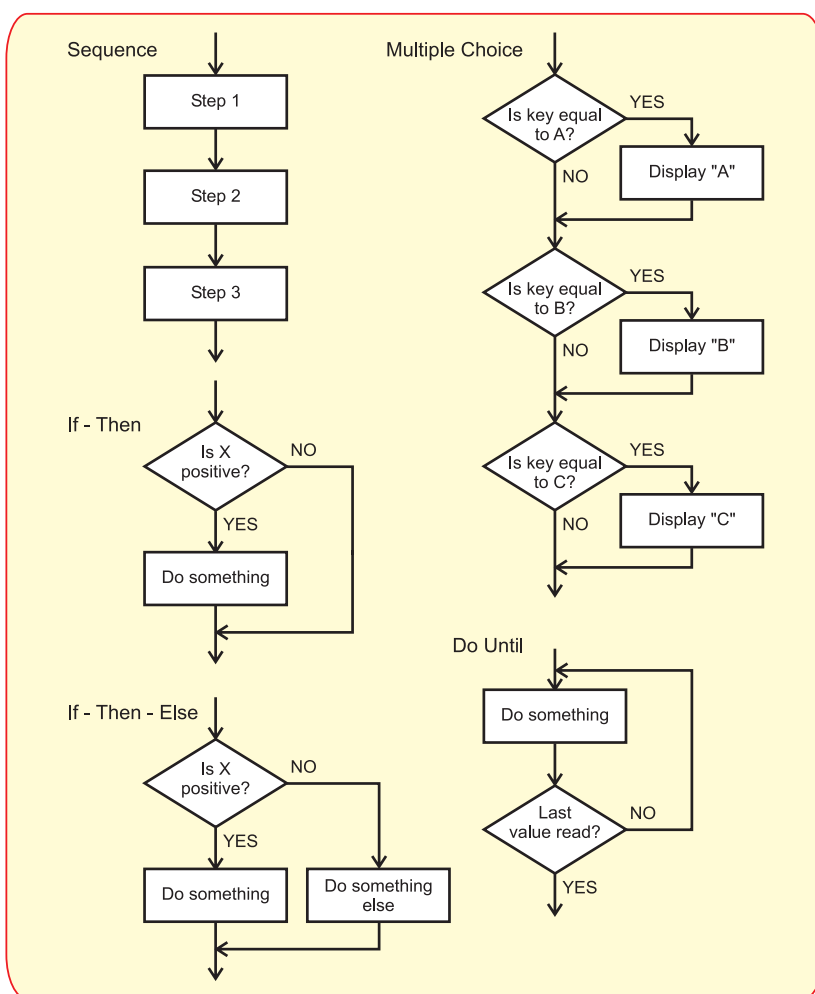


Fig 2: Program constructs

Inside the symbol you would write the name of the subroutine and any parameters that you would pass to it, for example 'DelayMs(10)' or 'Move(x, y)'. It's normal to use a language-independent style when describing the parameters that you pass, but at the end of the day use whatever system that suits you, something that you will understand at a later date.

Decision time

The **Decision** symbol is used to represent a branch within the program. One of the nice things about using flowcharts is that you are not forced to think about the actual *mechanics* of how branches are made ('do I test the carry flag, or the zero flag? Have I coded it the right way round?') Such questions can be left for much later.

Typically, Decision symbols have two exit points, with the 'normal' path following below, and the exceptional path leaving to the right. It's normal to have flowcharts start at the top of a page and work downwards, with branches heading off to the right. Sometimes it is sensible to have three exit points from a Decision symbol (such as when testing a variable for zero, negative or positive) but in most cases it is best to represent multiple decision branches as a series of Decision symbols, one below another.

The text within a Decision symbol is always phrased as a question, with the answers (representing the possible exit criteria) labelled on the flowlines that leave the symbol. Try to keep these labels brief or you will clutter the diagram.

The final symbol, **Input or Output** is really just a specialisation of the Basic Process symbol. It signifies an action in the program that requires some external interaction – such as a button press, displaying something on a screen or some exchange of information over a communication device – anything that involves the outside world as far as the program is concerned. You could use the Basic Process symbol to represent this if you wish, but using a different symbol for input/output activities draws one's attention to the point.

The full ISO flowcharting standard provides over a dozen different symbols for such 'special actions', but, in the author's opinion, the six symbols presented in Fig.1 provide enough detail for small microcontroller designs. You can, of course, explore the other symbols, or even invent your own – but those in Fig.1 provide a useful minimum.

There is one more symbol in Fig.1, the flowline. This is really the 'glue' that joins the symbols together. You draw a line from one symbol to another, indicating the direction of program flow with an arrowhead at the 'bottom' of a line to

show the destination. While the flow is normally from the top of a page to the bottom, program loops always require a return up to a previous symbol and so the arrow head is important.

Program constructs

The next step in explaining how to use flowcharts is to explain some common programming constructs, the basic building blocks of any program. We are all used to these constructs, but perhaps we are not familiar with their names. Some of the main constructs are shown in Fig.2.

The **Sequence** construct shows the typical, linear series of operations, one following another from top to bottom. The **If – Then** construct is a typical feature available in high level languages like BASIC and C; the ‘Do something’ block is skipped if the question inside the decision symbol is false. The **If – Then – Else** construct is a simple expansion of the previous example.

You might be thinking ‘But what if my decision has multiple outcomes?’ This is what language statements like ‘Case’ in BASIC are used for. These are handled as shown in **Multiple Choice**, with each possible outcome handled by a single decision symbol. It might look drawn out, but in reality this is how code created by a high level language would look. For people used to coding in assembly language it should look very familiar.

The final diagram in Fig.2 shows how the various **Do – Until**, **For**, and **While** loops are constructed. When the ‘exit’ test fails, a flowline points back up to an earlier symbol in the diagram – essentially a ‘goto’ in lower level languages.

The diagrams in Fig.2 show simple examples of the various programming constructs for clarity. Where a single block is shown on our diagrams, in real flowcharts you would often have several blocks, and

perhaps even multiple decision blocks. Just be careful to avoid getting into too much detail on higher level drawings.

Other constructs, such as ‘for’ and ‘while’ loops used in BASIC and C are just as easy to construct using the decision symbol and basic process blocks.

A real example of a flowchart, with the corresponding code, is shown in Fig.3. The code is for a ‘bit bashed’ RS232 receive routine (actually lifted from a previous article on Bootloaders). While the flowchart is clearly much larger than the source code, it’s a lot easier to read; especially if you don’t understand PIC assembly language! The diagram is at a relatively detailed level, especially as it makes reference to using the ‘Carry’ flag to store temporary information. On a higher level diagram this entire flowchart would be simplified to a single ‘Subroutine’ block, probably labelled ‘RxByte’.

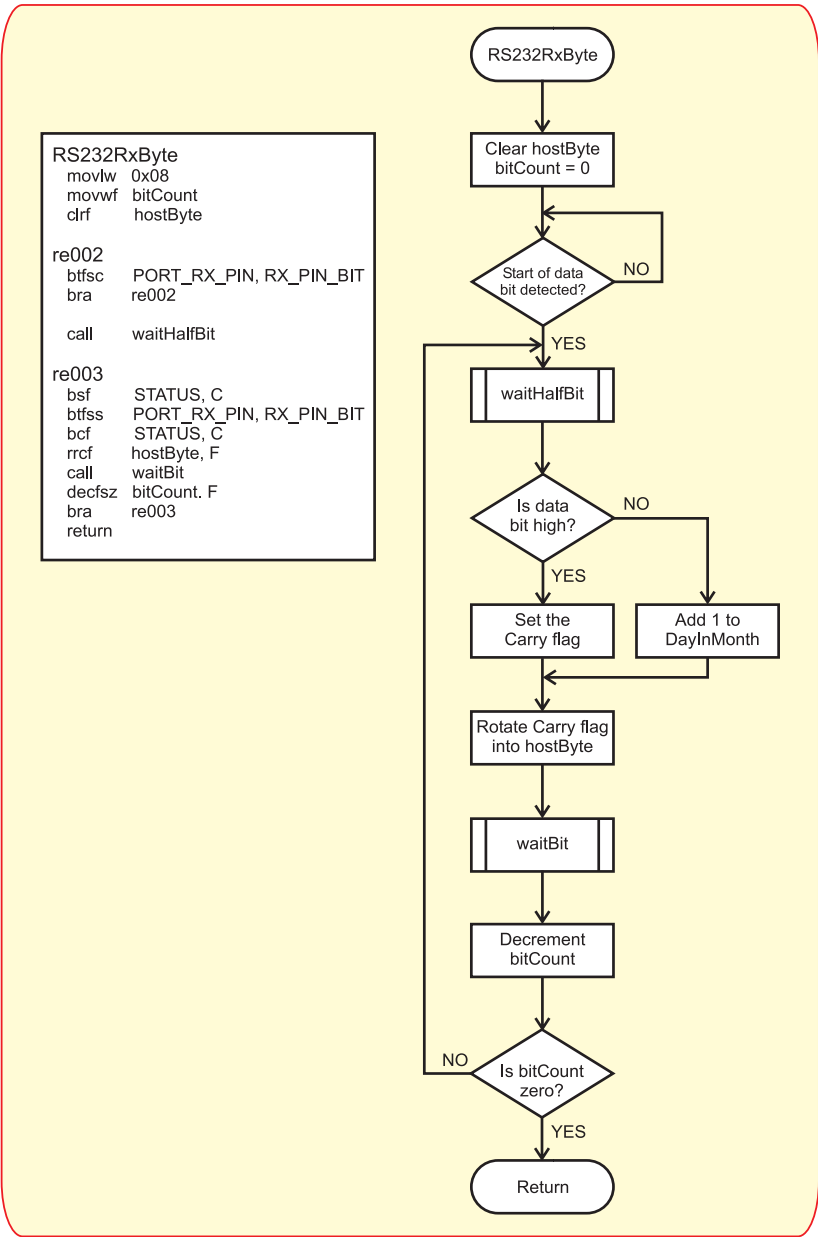


Fig.3: Comparision between a subroutine and its flowchart

Drawing tools

Drawing flowcharts by hand is quite easy for even the most artistically challenged, but correcting errors or inserting symbols is, of course, rather difficult. If you are going to be drawing lots of diagrams, or would like to produce something with a professional look, then there has to be another way.

Fortunately, there are many programs available now to help you draw flowcharts. Some are designed specifically for the purpose; others are simple drawing tools that can be used as an alternative to pen and paper. Fortunately for us, some of the better ones are completely free, available on the Internet.

The simplest option is to use a program available on all computers running Microsoft Windows – the humble ‘Paint’ program. You can draw the six flowcharting symbols, and simply copy them onto a blank page. For the most trivial of diagrams this can be quite acceptable, resulting in diagrams that you can save, print or incorporate into other documents.

The drawback with doing this is that the images are simply pictures – when you type in text, if there is insufficient space for the text you want to type, you have to re-draw the symbol. Much better are specialised drawing programs like Visio from Microsoft, or Dia, the latter being available for free on the Internet. Their features are very similar and since Dia is completely free, we will describe its use. Dia is the personal preference of the author for drawing flowcharts so there is a certain amount of bias here!

Using Dia

Installing Dia is simple. Simply download the setup program from the Internet address shown in the references at the end of this article, run it and the program will install in a few seconds. The setup program is a reasonable size, so it is only suitable for download by users with broadband Internet access. If you don’t have broadband access, find someone who has – it’s well worth the effort.

It's beyond the scope of this article to provide a tutorial on how to use Dia, but it is simple enough to pick up by trial and error. The program provides a set of template symbols for flowcharts, which you can drag and drop onto your diagram. Unlike the 'Paint' application, the symbols are designed to allow you to type text into them, and they re-size automatically as the text overfills the original shape. Drawing a diagram like that in Fig.3 takes just a few minutes (with practice).

Some programs take flowcharting to another level – they enable you to create programs automatically from the diagram.

One such program is Flowcode – available from *EPE* and, reviewed by Robert Penfold in the Aug '07 issue. Programs like this are commercial offerings and also tie you in to writing software in a particular way, which you may find too restrictive. With a simple, free program like Dia, you can create diagrams as they were originally intended – to help you design your program, making the task of writing code more pleasant!

Summary

It's not uncommon when writing a program to spend 80% of the effort designing with tools like flowcharts, and only 20% on

actually writing code. A flowchart provides an accurate, easy-to-read representation of how your software works and if created at the beginning of the project it will help you keep focused. With luck and practice, your designs will be good ones, ones to be proud of.

References

Dia – http://dia-installer.de/index_en.html

Flowcode – <http://www.matrixmulti-media.com/product.php?Prod=Flowcode%20V3>

<http://www.richardrandall.com/business/flowcharting.html>

<http://www.hci.com.au/hcsite2/toolkit/flowchar.htm>

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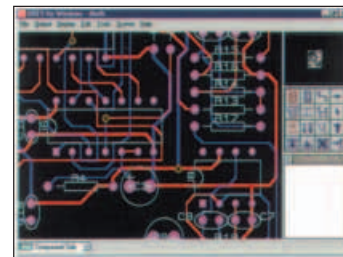


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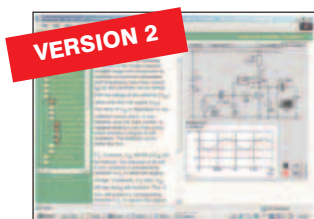
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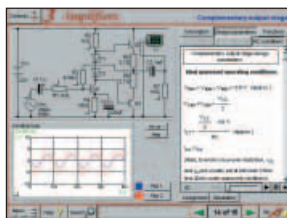
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Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: **Fundamentals**: units & multiples, electricity, electric circuits, alternating circuits. **Passive Components**: resistors, capacitors, inductors, transformers. **Semiconductors**: diodes, transistors, op.amps, logic gates. **Passive Circuits. Active Circuits. The Parts Gallery** will help students to recognise common electronic components and their corresponding symbols in circuit diagrams. Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

ANALOGUE ELECTRONICS

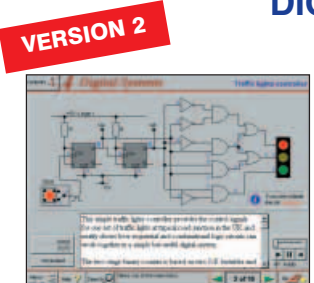


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.

Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections), Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0



Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen. Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

ANALOGUE FILTERS



Filter synthesis

Analogue Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

ROBOTICS & MECHATRONICS



Case study of the Milford Instruments Spider

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- Interactive Virtual Laboratories
- Little previous knowledge required
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PICmicro TUTORIALS AND PROGRAMMING

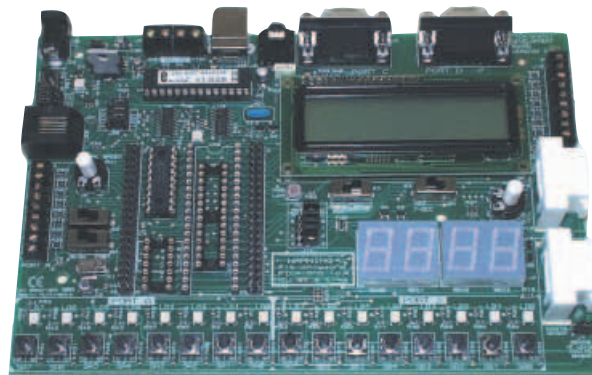
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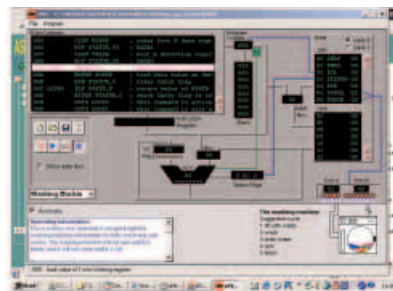
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SOFTWARE

ASSEMBLY FOR PICmicro V3 (Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes. The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller. This is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

- Comprehensive instruction through 45 tutorial sections
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- Visual representation of a PICmicro showing architecture and functions
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- Imports MPASM files.



'C' FOR 16 Series PICmicro VERSION 4

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Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

- Complete course in C as well as C programming for PICmicro microcontrollers
- Highly interactive course
- Virtual C PICmicro improves understanding
- Includes a C compiler for a wide range of PICmicro devices
- Includes full Integrated Development Environment
- Includes MPLAB software
- Compatible with most PICmicro programmers
- Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

FLOWCODE FOR PICmicro V3

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A Powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and I.c.d.s. The use of macros allows you to control these devices without getting bogged down in understanding the programming.

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
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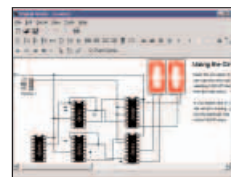
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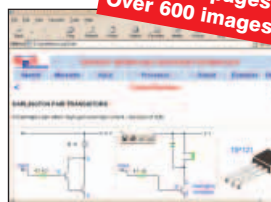
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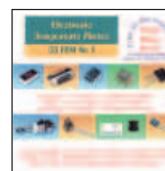
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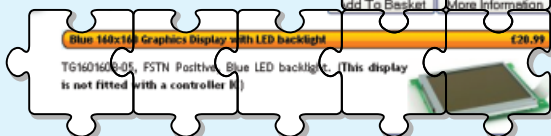
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The Power of Mechatronics

Part Six – A Simple Approach to RF Networking by Colin Greaves

CONNECTIVITY is a hot subject in the electronics world. Intelligent products controlling other intelligent products seem to be all around us. Not too many of us own, or see the need for an internet capable refrigerator, but products which can communicate security information, or state of repair are not only being developed right now, but are out there – talking to each other.

Wire-free communication is one of the factors required to make such developments possible, and radio is probably the most flexible medium to provide this. Point-to-point radio modules have been successfully used by the million in everyday products, such as key-fob car entry systems, toys, and other simple cable replacement applications. Using radio for connecting several devices together needs a bit more thought though, and more control. Thankfully, a lot of this work has been done for us, and what we are left with can be delightfully simple to use!

So, you plan to put together a radio-based monitoring system in your house, a temperature sensor in the greenhouse, a rain detector outside, and a flood warning device in the basement! What are the first considerations? Power consumption? Radio range? These may be your first thoughts, but with some understanding of what types of radio network configurations are available, a suitable solution can be found.

Another consideration will be what frequency to operate on. Popular ISM bands at 868MHz (915MHz Americas) and 2.4GHz both have benefits and drawbacks. Generally, when people look at networking with radio, with protocols like ZigBee or MiWi, they are drawn to the globally accepted frequency of 2.4GHz, with 16 channels available for network selection.

Topologies

When considering the use of a network, it is necessary to decide how the nodes on the network will work together, what communication paths will be used. The simplest network arrangement is a star topology. In this configuration, a central hub, or coordinator is used to communicate to all of the sub-nodes on the network, as in Fig.1.

This arrangement has advantages – the sub-nodes, or end devices can all be functionally very simple with small memory requirements, and be capable of low power



Fig. 1. Star and cluster tree arrangement

(sleep) modes. A major disadvantage is robustness – if the central coordinator should fail, then the whole network will fail.

This type of network is also limited in radio range to twice the distance of the radio transceiver range. This can be addressed by using another type of device in the network; a router. Using this type of node, the network can be extended from a simple star, to a cluster tree of star networks (Fig.1), talking to each other via a central trunk.

The failure of a single coordinator node in a cluster tree can also devastate network operation, so a third kind of network topology is sometimes used, a mesh network. In this type of arrangement, all of the nodes can talk to each other, without having to rely on one central device to get messages onto the network. This is a robust configuration, but has a large overhead in terms of resources, such as network traffic, memory requirements of the units, and also, power consumption.

Reliability

With so many radio transmissions flying about, collisions between messages are going to be a real problem. In a typical network, several devices will be in radio range of each other, so we need a way to avoid corruption of messages by collision. Two types of message collision which are often employed in networks are Carrier Sense Multiple Access – Collision Avoidance (CSMA-CA) and Collision Detection (CSMA-CD).

A radio network is usually not able to detect collisions in the message transmissions, as the units are not normally able to talk and listen at the same time. They are either in transmit or receive mode, and so Collision Detection is not normally an option, which is why Collision Avoidance is used.

In practice, CSMA-CA is just a matter of listening for active transmitters before you make a transmission yourself – in much the same way people do, they listen for a pause in the conversation before they speak. Well, at least most people do!

As our radio network is unable to detect a collision, a good idea is to request an acknowledgement that the message was received. In fact, the IEEE 802.15.4 layers require that every transmission is followed by an acknowledgement of receipt. This handshaking forms the basis of reliability that most applications require. A message originating from a node will be acknowledged by the receiving node, then that node in turn will receive an acknowledgement as it passes the message on.

Security

Some applications might need to protect their transmissions from prying eyes, or ears! A radio mouse or a gamepad/console arrangement would probably not require their transmissions to be secure by encryption, but a keyboard or a security system certainly would.

The addition of a 128-bit Advanced Encryption Standard (AES) into the IEEE 802.15.4 protocol opens up the use of radio networking to the security conscious market. AES is the replacement for the very popular Triple-DES which is still very popular with the electronic payment industry. This level of security is considered sufficient for the vast majority of secure communication requirements.

A practical implementation

Looking at the above information, it would appear that the IEEE 802.15.4 standard is a good basis for a radio network, and it does in fact provide a good platform to construct a network. The standard OSI

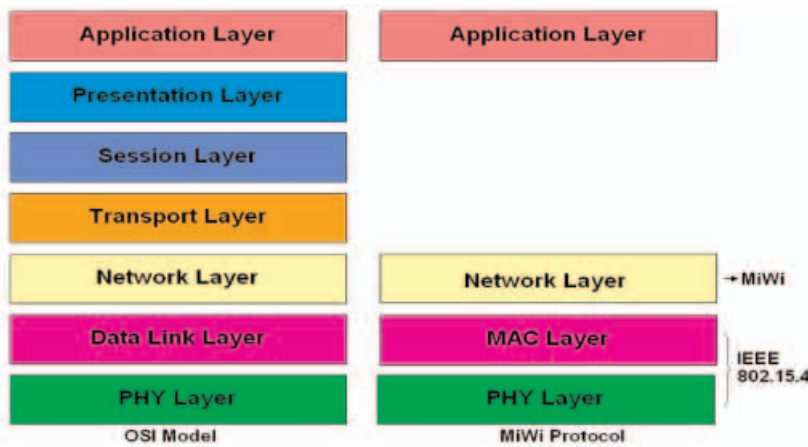


Fig.2. The lower three layers are used to implement a radio network – it is not normally required to use all seven layers of the OSI model for any network solution

Network model 802.15.4 provides the two lower-most layers (Fig.2) and requires a further layer to open up the networking features we have discussed.

One such option for the network layer is ZigBee. This protocol has been in the electronics press quite a lot lately, and is the brainchild of the ZigBee Alliance, a group of companies from all over the world. The outcome of their efforts is a suite of communication protocols which can be used to address large, complex networks, and will also provide interoperability between different manufacturers' products using the ZigBee protocol.

Given the complexity of a ZigBee network, a simpler networking solution was sought by many designers, and Microchip developed the much simpler MiWi network protocol. Let's have a look at some of the features of this protocol.

MiWi – a simple network solution

A MiWi network is constructed from two types of device. The first is a Full Function Device (FFD) and is given the task of coordinator function. The FFD will provide an entry point onto the network for the second type of unit, the Reduced Function Device (RFD).

The RFD is the type of unit that is battery powered, and sits on a wall monitoring a switch or thermistor, or sensing movement. It conserves power by just activating its transceiver when it needs to, very quickly joining the network, reporting, then shutting down again. This low duty cycle of operation is how it can achieve months or years of battery life from primary type cells.

In order that the RFD messages are received when it eventually transmits, the FFD must be awake and listening, and will therefore normally be a fully powered product. The FFD will also buffer messages for its own RFDs from other units, to be passed on to them when they wake.

Addressing

When a MiWi network is initialised, the first coordinator to come online will assume

the role of the whole network coordinator, called the PAN coordinator (Personal Area Network). The PAN coordinator will choose a suitable channel from the 16 available (at 2.4GHz) and establish a network address. It will then assign a number between 1 and 7 for all subsequent coordinators that join the network, address 0 being reserved for the PAN coordinator itself.

The group of coordinators will form the backbone of the network, and will provide a host function for the suite of RFD end devices which want to join the network. Each RFD will be given a number by its parent coordinator, from 1 to 127. A MiWi network can therefore support up to eight lots of 127 nodes, plus the coordinators, giving 1024 nodes. This is somewhat less than the 64k nodes supported by ZigBee, but is more than sufficient for the majority of applications.

One of the requirements of a ZigBee router is to store routing tables for the nodes on the network. This needs quite a chunk of memory to achieve, and so eliminating this would be desirable.

MiWi has a much smaller memory requirement than ZigBee, the RFD needing a minimum of only 4kB, and the FFD being achieved in less than 16kB. By comparison, a ZigBee RFD needs something like 32kB and the FFD in the order of 64kB. This minute footprint of MiWi is down to a simplified approach, and the clever way in which routing and addressing is achieved.

Two types of addressing are implemented on the network – long addressing and short addressing. The IEEE protocol 802.15.4 requires that a unique 64-bit address is allocated to each product that is manufactured, and in fact sells them in blocks of several billion, in much the same way as Ethernet addresses are distributed. This unique

address is the long address of the unit, and can be used within a MiWi network to address a message to an individual unit. This might be sufficient for some applications, but it doesn't actually contain any information on the location of the unit within the network, or how to route messages to it.

Short addressing

The second addressing mode, short addressing, is the preferred way to send messages. This is a 16-bit address, constructed to identify the position of the unit on the network.

Looking at the structure of the MiWi short address in Fig.3, we can see that the parent coordinator number and the child number form the basis of the address. In this way, each node on the network can be given a unique address with respect to its location.

The first five bits of the short address are unused (and available for user definition if needed). The three parent bits define the coordinator number, and the last seven the child number of that coordinator. The single RxOffWhenIdle bit informs the network of the low power mode status of the device being addressed – a 1 in this location signifying that the device has a sleep mode.

To understand the construction for short addressing, we must take a look at how devices are numbered on a MiWi network. A coordinator assigned the number 1 might have 12 child devices, child number 5 being a light bulb controller. The short address for the coordinator itself would be 0 1 0 0 (0x0100 hexadecimal). Note that the last byte set to all zero is an indication of no child number, 'I am a coordinator unit'. Shown in Fig.4, the light bulb child would have short address 0x0105 meaning the 5th child of coordinator number 1.

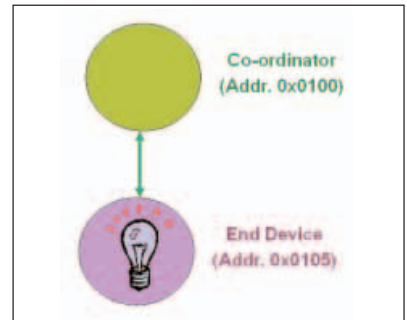


Fig.4. The 5th child of coordinator number 1

One of the addressing modes of ZigBee and MiWi requires units to have multiple pathways, and not just rely on a single join point into a network. We mentioned this as mesh networking MiWi permits this multiple pathway access by allowing each end device to talk to multiple coordinators, or to all of them if required.



Fig.3. Structure of the MiWi short address

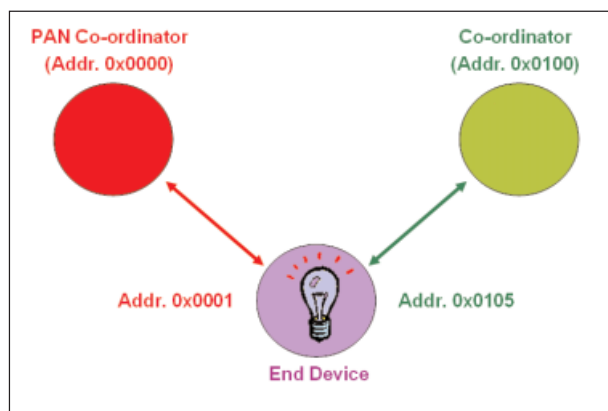


Fig.5. End device, child 5, connected to a second coordinator

Fig.5 shows the same end device now connected to a second coordinator, in this case, the PAN coordinator itself. The PAN coordinator has a number 00, and therefore short address 0x0000. Our light bulb connects to this device as its first child, and is given child number 01, so the light bulb unit has a second short address of 0x0001.

It now has two short addresses on the network – which is correct? Well, they both are. Either short address can be used to reach the device, allowing redundancy in case of unit failure. It seems then, that sending messages around a MiWi network might be pretty straightforward. How does the software, the MiWi stack actually enable this?

MiWi stack

The stack is basically the software which runs the network on top of the 802.15.4 MAC layer. This network layer is accessible by the user with a set of function calls.

The following list of function calls are the basics of what are needed to open a network, join it, communicate and so on. These are some of the functions we have discussed, and are listed in much more detail in the Microchip applications note AN1066, downloadable from their website.

```
DiscoverNetwork();
FormNetwork();
JoinNetwork();
SendReportByShortAddress();
SendReportByLongAddress();
```

Note that the messages sent across the network are called 'reports' and can contain user application data, or status information.

The MiWi stack can also be downloaded from the Microchip website; type www.microchip.com/miwi into your browser to find the page. With the download, you get a very useful tool, called Zena. This is Microchip's front end software for their network analyser board – very useful for monitoring the messages being sent around your network. They are displayed on a PC screen in real time, and allow the developer to see all of the information contained in their MiWi (or ZigBee) network messages.

Zena

Zena also has another useful feature. It allows us to set up the stack according to

what type of PIC we have chosen to use, what I/O we want to use, low power modes, whether it is an FFD or an RFD, what channels to use, and so on. All of these options are entered into a wizard using checkboxes or values, and are used to build your MiWi stack file MIWIDefs.h. This makes the setting up of a MiWi project very simple (Fig.6).

Device selection, RF operation, security options and other configuration data are set using Microchip's front end wizard to quickly generate project header files. Once all of the options have been ticked in the boxes, the Generate Files button at the bottom is pushed.

Hardware

The MRF24J40 is the 802.15.4 transceiver used as a basis for Microchip's MiWi and ZigBee platforms. The hardware is identical for each platform, and is available as a demo kit. Let's have a look at the transceiver (Fig.7).

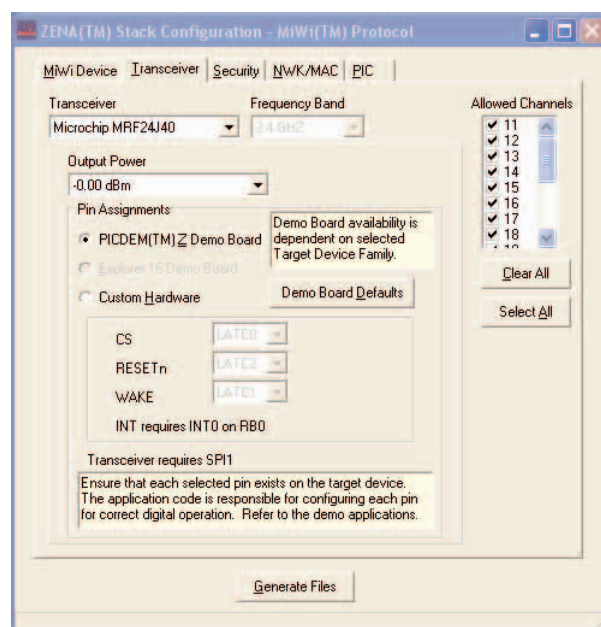


Fig.6. The Zena configuration tool for MiWi and ZigBee stacks

As shown previously, the MRF24J40 contains both the MAC and the PHY levels of the communications stack. Tx and Rx buffers and the security engine is also included in hardware – this is how the MiWi memory footprint can be so small, even with encryption turned on. The MAC will also handle your re-transmits for you, should the acknowledgements not be received – the hard jobs are all done in hardware!

The interface to the host PIC controller is through a synchronous serial port, or SPI interface. The communication into the transceiver is all taken care of by the stack, the user doesn't need to worry about this function. However, like other Microchip solutions, the full MiWi and ZigBee stack source code is given in the download, and all such functions are available for user inspection.

Another useful point is that MiWi is completely proprietary to Microchip. The user doesn't have to worry about modifying the code to their own needs, they are perfectly free to do so. ZigBee, on the other hand, is carefully regulated by the ZigBee Alliance, so making changes to the ZigBee stack can invalidate your approvals process.

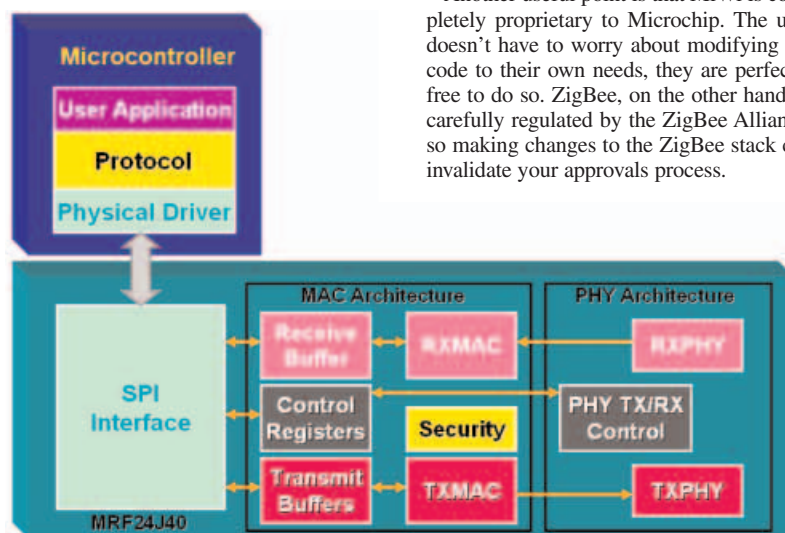


Fig.7. Transceiver block diagram

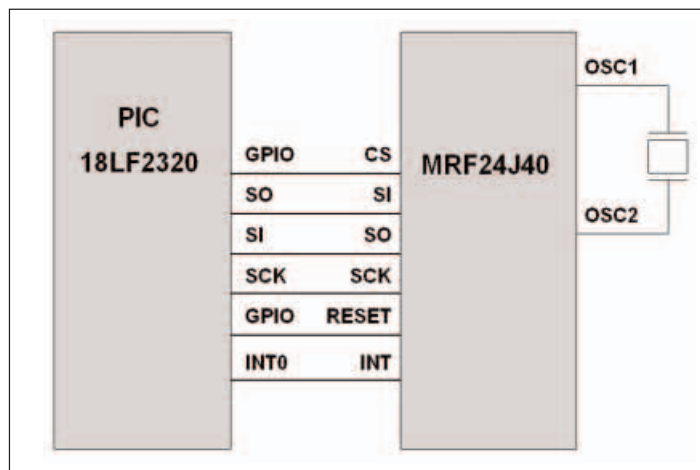


Fig.8. The Microchip MRF24J40 transceiver supports a simple SPI type interface

The actual user application is all that remains to be written and compiled into the PIC. At this point, you look at your hardware peripheral requirement (do I need USB? Ethernet? ADCs?) then choose your PIC to host the MiWi stack. This may be a simple PIC16F, the popular PIC18F series with their multitude of peripheral functions or one of the high performance PIC24F parts depending on your application requirements – MiWi will run on most of the range of devices.

The Microchip MRF24J40 transceiver supports a simple SPI type interface. Many of the PIC range have this type of synchronous serial capability, and will happily

support the device. The rest of the interface is simple chip control and interface (Fig.8).

The next step

Have a look at the MiWi page on the Microchip website. Download the apps notes, and the free stack, and start playing. The stack source code is well documented and supported with applications notes, and is easy to follow.

Also available is the PICDEM-Z development kit (part number DM163027-4), Fig.9, which provides the developer with two MRF24J40 transceiver boards, two development boards to run the stack on, and a Zena

network analyser board which plugs into the USB port of your PC. This is a good kick-start to get your project up and running! **EPE**

References:

Microchip MiWi stack – www.microchip.com/miwi

Microchip ZigBee hardware tools – www.microchip.com/ZigBee

Microchip MRF24J40 – www.microchip.com/MRF24J40

Colin Greaves will be delivering a MiWi workshop at the Microchip European MASTERS event in Munich from 6th to 8th November.

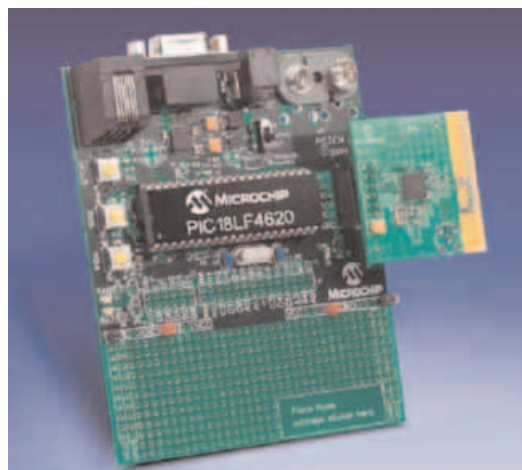


Fig.9. PICDEM Z 2.4GHz demonstration board

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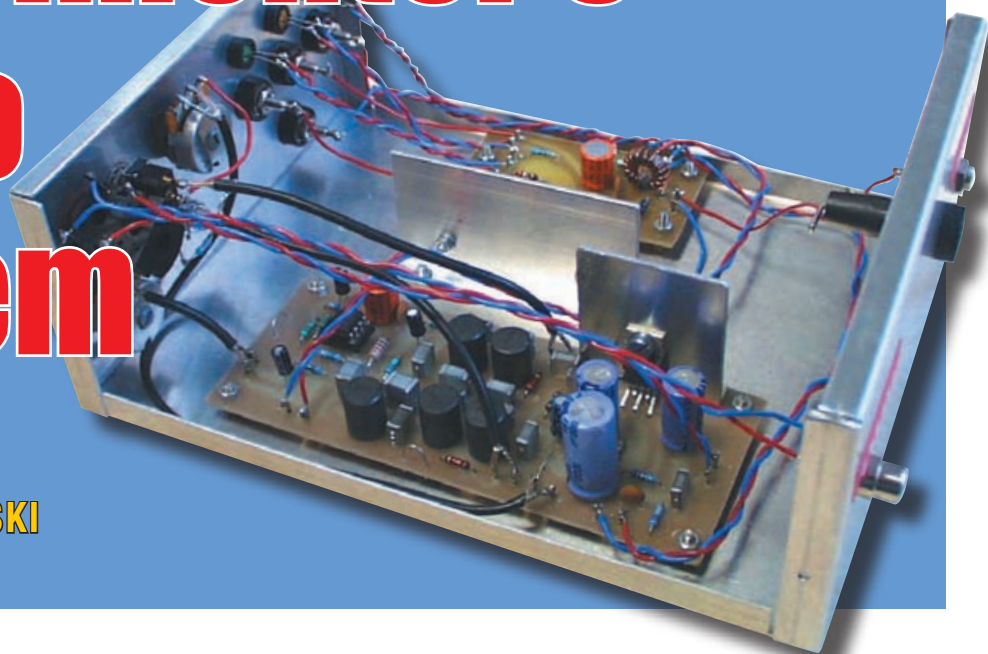
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Experimenter's Audio System

By STEF NIEWIADOMSKI



Audio preamp, filters, power amplifier and power supply for radio experimenters

If you like to build radio receivers and experiment with 'front ends', it can be very useful to have a unit on the bench which takes the low level audio from the front end, then amplifies, filters and boosts it to loudspeaker or headphone volume.

Another useful piece of gear to have is a stabilised power supply unit (PSU), capable of generating different DC voltages to power the receiver front ends.

The unit described here combines these useful functions, and consists of

a high gain audio preamp, switchable audio filters and power amplifier, as well as having three different stabilised DC voltage outputs. The emphasis of the unit is to achieve high quality and low noise, while keeping the cost low and, of course, using easy-to-get components.

The unit is powered from a cheap external 12V PSU, and this saves the cost and complexity of an in-built mains powered supply. It also has the advantage

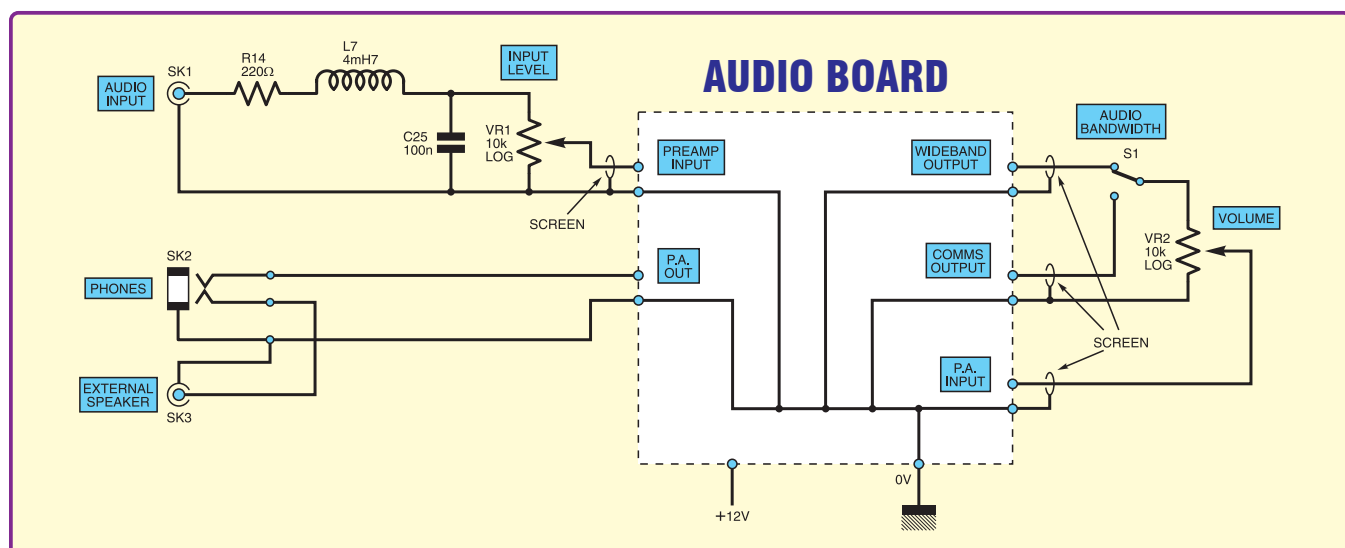


Fig.1: Block schematic diagram showing the signal inputs and outputs to the preamp, filters and PA amp

that the risk of mains-induced hum can be kept out of the unit.

The design can be used as a self-contained bench unit, or alternatively the printed circuit boards can be incorporated into a new receiver you might be working on, taking away most of the audio and PSU design work, and allowing you to concentrate on the all-important front-end and detector stages.

Inputs and outputs

The circuit diagram in Fig.1 illustrates the signal inputs and outputs as connected to a block diagram representing the preamp, filters and power amplifier, which are shown separately later.

The audio input to the preamp comes via phono socket SK1 and is then filtered of any RF (radio frequency) content by resistor R14, RF choke L7 and capacitor C25. The network formed by these components has very low impedance at audio frequencies, but an attenuation of more than 70dB at 455kHz, which is a typical intermediate frequency (IF) used in receivers. There is increasing attenuation at higher frequencies.

Potentiometer VR1 acts as an input level control, the wiper of which feeds the signal to the preamp. The output paths will be discussed as we progress.



Fig.2: General layout of front panel components

Preamp circuit

The circuit diagram for the audio preamp and audio filters is shown in Fig.2. IC1 forms a conventional inverting op amp, the gain of which is defined by resistors R3 and R5. With the values shown, the gain is 100, or 40dB.

Components R1, R2, R4 and C2 form a decoupled mid-rail supply for the non-inverting input of the op amp, which means that a split-rail supply does not have to be provided. This considerably simplifies the power supply design for the unit, as described later. RF choke L6 and capacitors C3, C4 decouple and filter the supply rail to IC1, preventing any RF or lower-frequency noise from influencing it.

During development, several pin-for-pin compatible devices were tried for IC1 and the effect on overall output noise was subjectively checked. Suitable devices for IC1, in order of low-to-high cost and performance would be: TL071, OP07, NE5534N then the OP27. If you are willing to pay the price for a superbly low-noise op amp, then go for an AD797.

Via capacitor C5 and resistor R6, the output of IC1 drives a 6kHz cut-off frequency five-stage elliptic lowpass filter comprising L1, L2 and capacitors C6 to C10. L1 and L2 are ready-wound Toko inductors, so no difficult inductor winding is necessary.

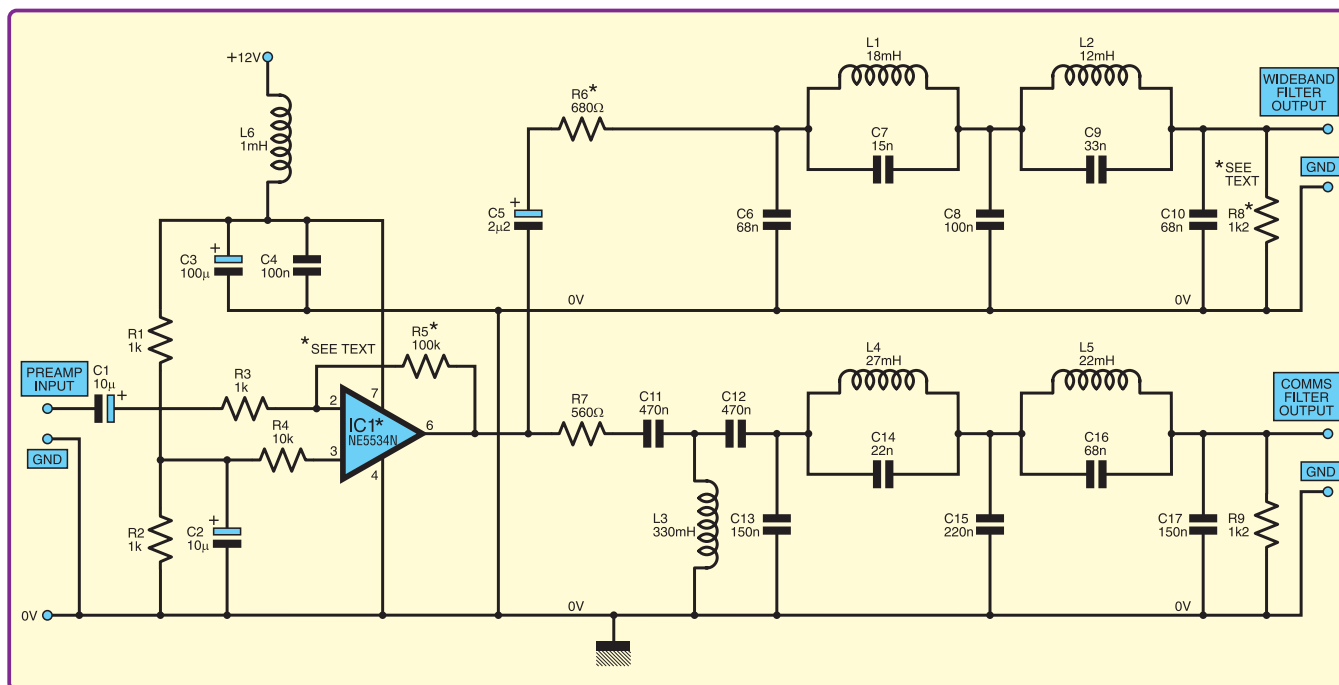


Fig.2: Circuit diagram for the audio preamplifier and filters. With the values shown, the gain is 100, which is 40dB

The value of C5 has been chosen to add a mild highpass response to this filter, thereby flattening the low frequency response. Resistor R6 matches the low impedance output of the op amp to the drive impedance of the filter. The filter is terminated with an impedance of about $1k\Omega$, formed by the parallel combination of resistor R8 and, as shown in Fig.1, the volume control VR2. This filter can be used for listening to relatively wideband AM or FM broadcast stations.

The communications-class filter stage in Fig.2 consists of a 300Hz 3-pole highpass filter, comprising capacitors C11 and C12, plus inductor L3. It is cascaded with a 3kHz five-stage elliptic lowpass filter, comprising capacitors C13 to C17, plus inductors L4 and L5. This filter is for use when receiving SSB/CW transmissions, cutting out low and high frequency interference.

This filter reduces the audio bandwidth of the received signal, but greatly improves intelligibility, especially under difficult listening conditions. It is driven via resistor R7 and terminated by the parallel combination of R9 and, as in Fig.1 again, volume control VR2, with switch S1 selecting which filter is used.

The responses of the wideband and communications-bandwidth filters are shown in Fig.3. The rapid roll-off of the filters can be seen, plus the troughs of attenuation in the stopband, both of which are characteristic of elliptic filters.

Care has been taken to choose Toko inductor values which are easily available for the filters, as these components are getting more difficult to obtain.

Referring to Fig.1, toggle switch S1 selects the output of one of the audio filters, and whichever one is selected feeds the audio power amplifier, IC2, via the volume control VR2.

Power Amplifier

From volume control VR2, the signal is fed to the power amplifier, whose circuit diagram is shown in Fig.4.

A TDA2003V has been chosen as the amplifier device, IC2, as it has more than adequate power output (10W maximum, designed for use in car radios), and is cheap and easy to obtain. It has very low harmonic and crossover distortion.

The components surrounding IC2 are taken straight from the data sheet.

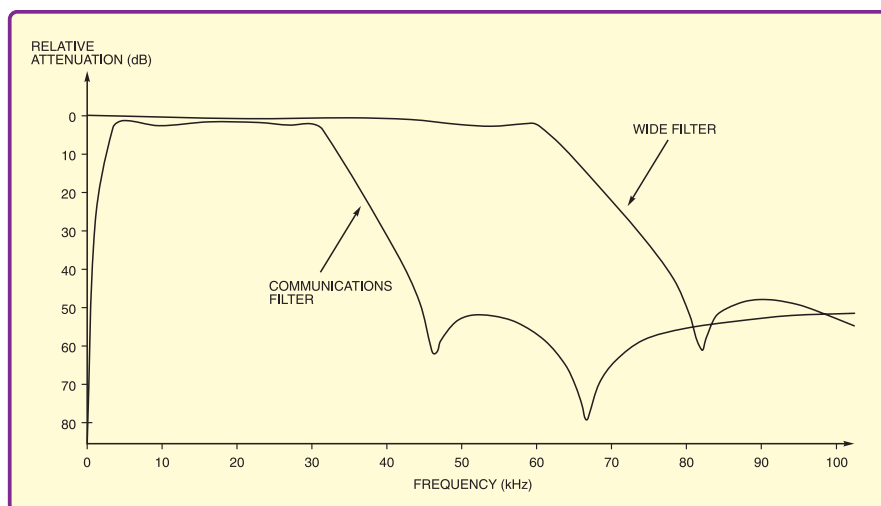


Fig.3: Graph showing response of the wide and communications bandwidth audio filters

Capacitor C18 blocks any DC voltage on the audio input, while capacitors C20 and C21 decouple IC2's supply from noise and prevent oscillation caused by supply current peaks. Capacitor C23 couples IC2's output to the load, again removing the DC component, which would otherwise damage the phones or loudspeaker.

Capacitor C22 and resistor R13 set the upper cut-off frequency of the amplifier. The network formed by resistors R10, R11 and capacitor C19 sets the gain of the amplifier and supply ripple rejection. Finally, capacitor C24 and resistor R12 form a Zobel network, commonly seen on the outputs of integrated circuit audio amplifiers, which prevents oscillation at high frequencies with inductive loads.

Referring back to Fig.1, the audio

output feeds the headphones socket, SK2, which cuts the connection to loudspeaker socket SK3 when the phones are plugged in.

CW audio filter

The circuit diagram for an 800Hz CW (continuous wave) filter is shown in Fig.5. This filter can be built in place of the wide-band filter in Fig.2, with no PCB tracking changes. Simply substitute the CW filter component values shown in the schematic for resistor R6 and inductors L1, L2, and capacitors C6 to C10.

Note that resistor R8 is not fitted for the CW filter, the $10k\Omega$ resistance of potentiometer VR2 provides the only termination for this filter. This results in less insertion loss for this filter and less 'sag' in the response close to cut-off.

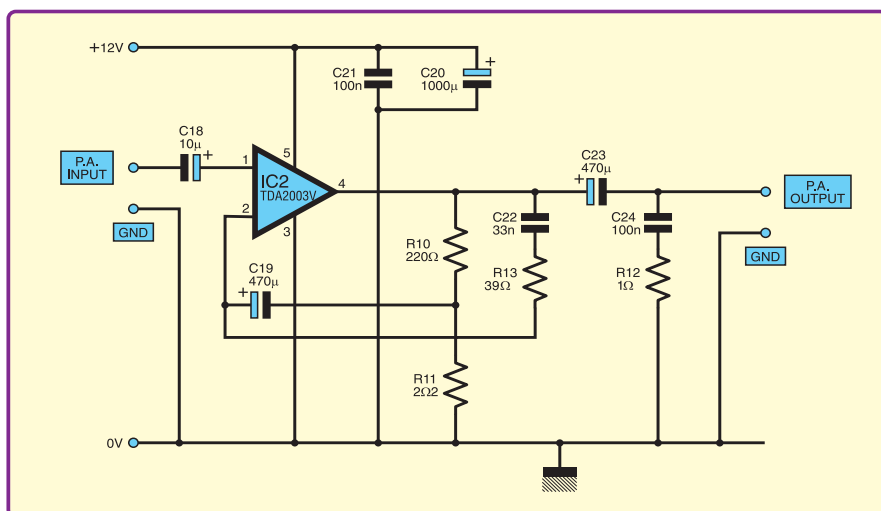


Fig.4: Circuit diagram for the power amplifier section

Power supply

The circuit diagram for the stabilised power supply is shown in Fig.6. An external 12V DC supply source is connected via socket SK4 and fuse FS1. The supply is filtered by RF choke L8, plus capacitors C26 and C27. These components are included because the low-cost switched-mode power supplies suitable for using with this unit have a few millivolts of high-frequency ripple on their DC output line. It is best to remove this as close as possible to the input of any unit being powered.

Diode D1 helps to protect the circuit from incorrect connection of the supply polarity. If the external supply is

connected correctly, the diode never conducts and all is well. However, if the supply is reversed, D1 conducts heavily with only about 0.7V across it, and sufficient current flows to blow fuse FS1 within a few hundred milliseconds, hence disconnecting the supply and protecting the unit from damage.

The filtered 12V rail feeds directly to socket SK5, and also supplies voltage regulators IC3 and IC4, which produce stabilized +9V and +6V outputs on sockets SK6 and SK7, respectively.

Although not strictly necessary, LEDs D2 to D4 indicate the presence of the three voltage levels. Resistors R15 to R17 limit the current through the LEDs to 10mA.

Socket SK8 is connected to the metal ground of the unit, to which the 0V planes on the boards and the negative side of the external supply are connected.

Construction

The unit is built on two printed circuit boards, whose component and track layout details are shown in Fig.7 (Audio) and Fig.8 (PSU). These PCBs are available from the *EPE PCB Service*, codes 645 (Audio) and 646 (PSU).

Mount the components in ascending order of size, taking care to correctly orientate the semiconductors and electrolytic capacitors. Use a DIL (dual-in-line) socket for IC1, but do not insert IC1 until the power supply and general construction has been fully checked.

Amplifier IC2 comes with its leads already formed and is mounted vertically on the board. It should not be possible to mount it incorrectly. Before soldering IC2, mount it loosely on its heatsink (which needs to be drilled to suit, see Fig.9) and check that the holes in the PCB and those in the heatsink line up. Ensure that IC2 is not put under any mechanical stress when assembled on the heatsink and soldered on the board. Its metal tab is

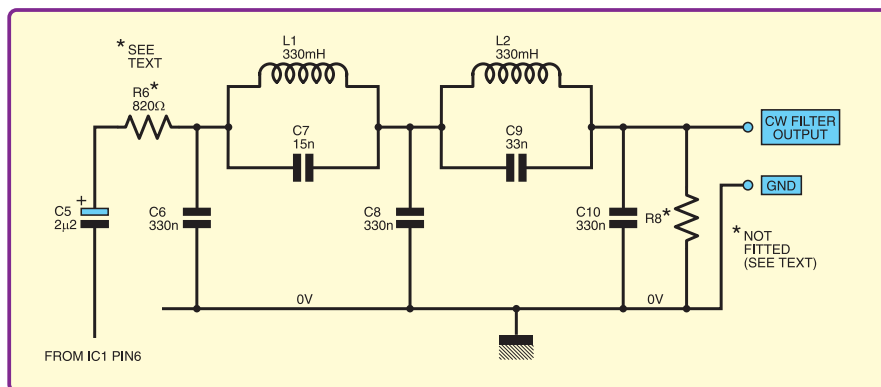


Fig.5: Circuit diagram for an 800Hz CW filter. This filter can be built in place of the wide-band filter (Fig.2), without any PCB changes (see text)

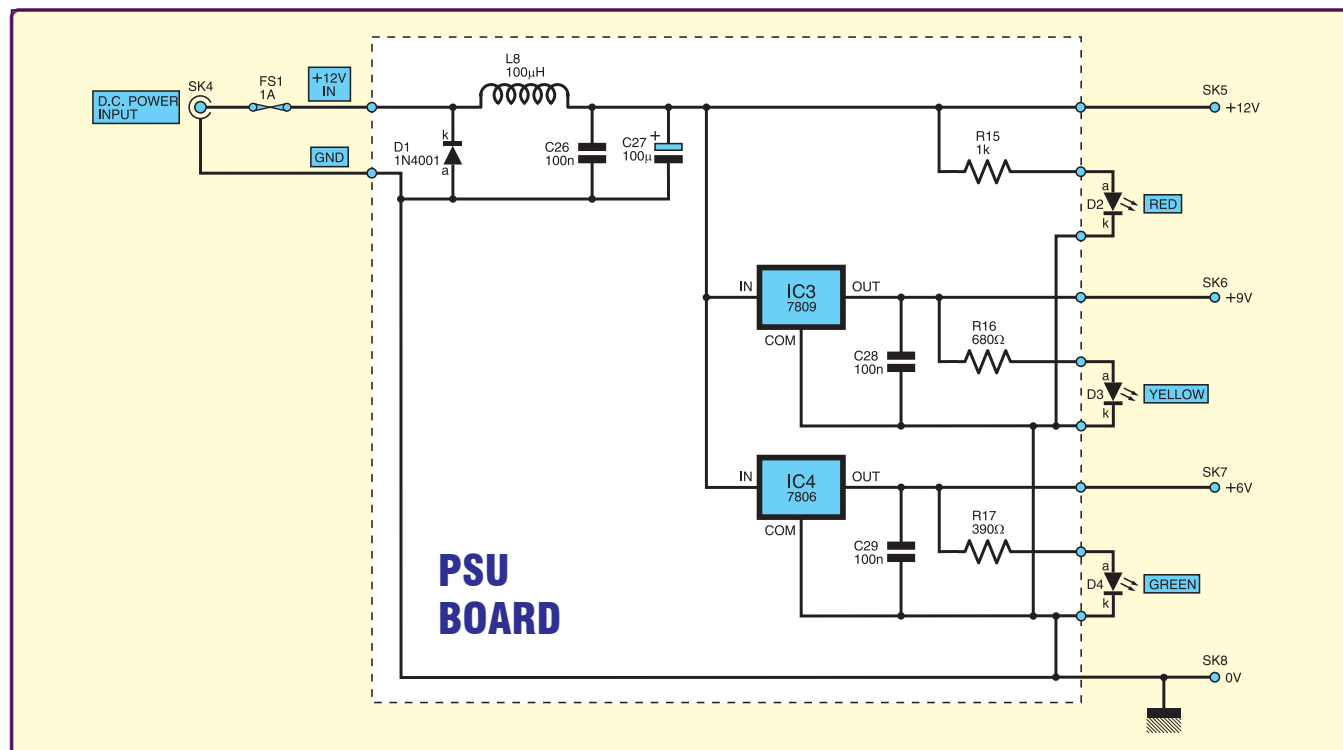


Fig.6: Circuit diagram for the stabilised power supply stage of the Experimenter's Audio System. An external 12V DC supply 'plugpack' is connected via socket SK4 and fuse FS1

AUDIO AND FILTER BOARD

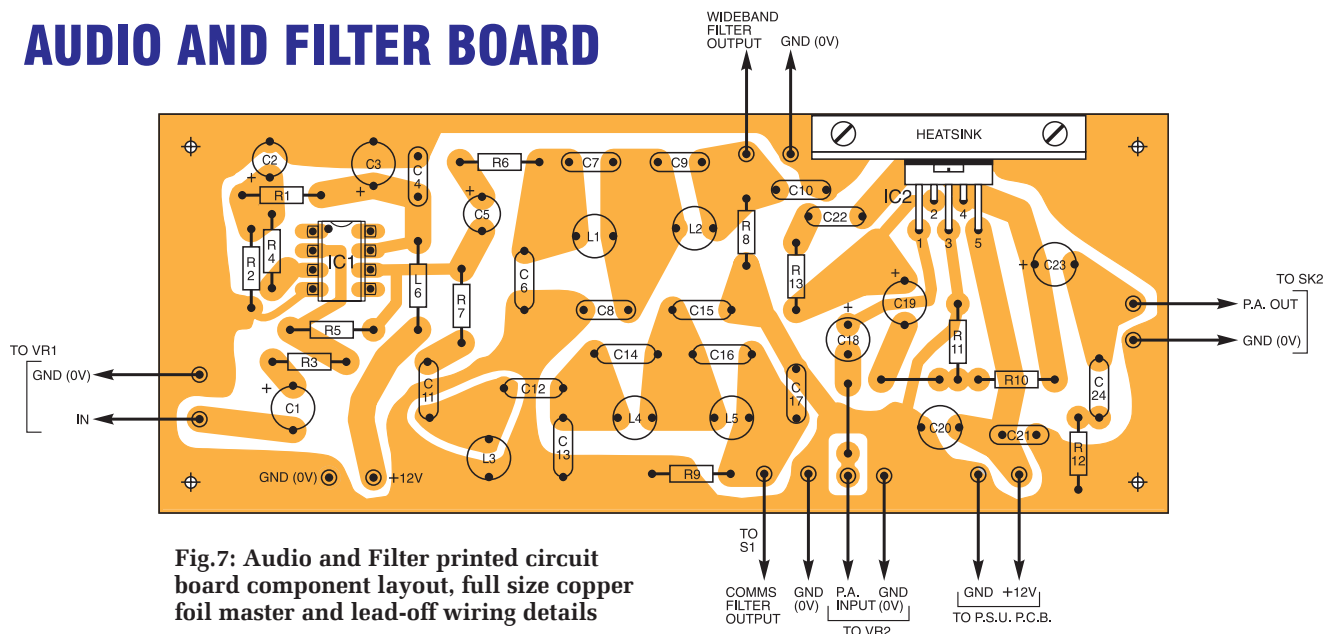
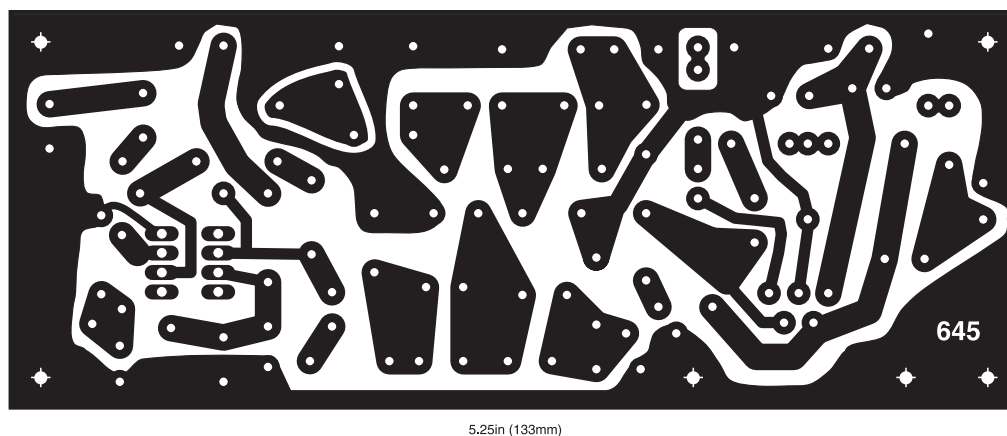


Fig.7: Audio and Filter printed circuit board component layout, full size copper foil master and lead-off wiring details



PSU BOARD

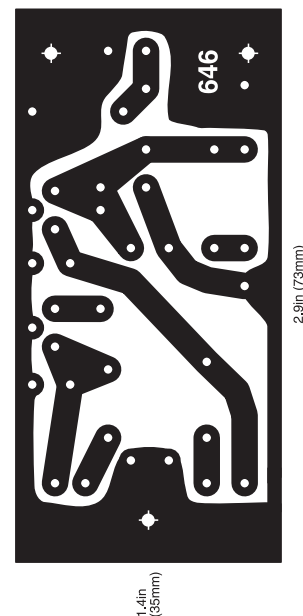
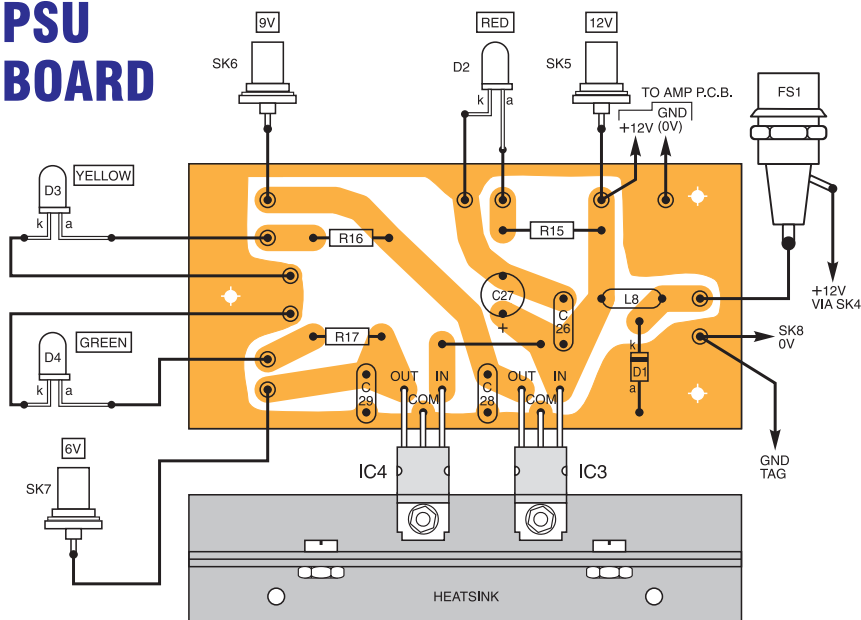


Fig.8: Power supply construction and wiring details and full-size copper track master

connected to its ground pin (0V) and so an insulating kit is not needed.

Insert 1mm terminal pins for all off-board connections.

The leads of IC3 and IC4 need to be bent through 90 degrees and the middle lead offset from the outer ones, so that the regulators project horizontally from the PCB for mounting on a common heatsink. This heatsink is made

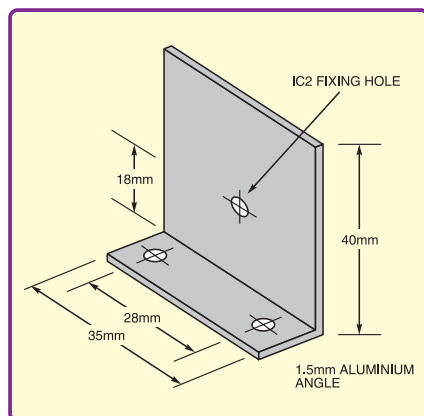


Fig.9: Amplifier IC2 heatsink details

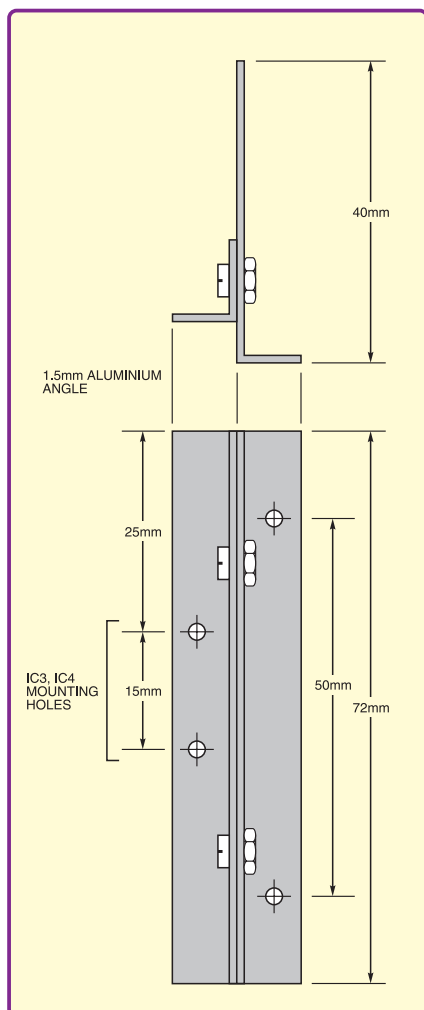


Fig.10: Heatsink details for voltage regulators IC3 and IC4

from two pieces of aluminium angle bolted together and drilled appropriately (see Fig.10). Some juggling of the heatsink position and the height of the PCB above the chassis may be

needed to ensure that IC3 and IC4 are not stressed in the final assembly.

Rather than using an off-the-shelf inductor for choke L8, the author wound his own. The reason for this

Parts List – Experimenter's Audio System

- 2 PC boards, code 645 (Audio) and 646 (PSU), available from the *EPE PCB Service*, sizes 133 x 53mm (Audio) and 73 x 35mm (PSU)
- 1 aluminium two-piece case, size 200 x 150 x 75mm
- 1 20mm chassis-mounting fuseholder, plus 1A fuse (FS1)
- 1 SPST min. toggle switch (S1)
- 2 phono sockets (SK1, SK3)
- 1 switched jack socket, size to suit headphones (SK2)
- 3 'banana' sockets/screw terminals, red (SK5 to SK7)
- 1 'banana' socket/screw terminal, black (SK8)
- 1 2.5mm DC power input socket (SK4)
- 1 12V DC power plugpack – see text
- 1 8 ohm min. loudspeaker – see text
- 3 LED mounting clips (D2 to D4)
- 2 plastic knobs (VR1, VR2)
- 1 8-pin DIL socket

Aluminium angle strip for IC2 to IC4 – see text and Figs.9 and 10;
0.56mm (24s.w.g.) enamelled copper wire – see text; earth solder tag; screened audio cable; single-core, or multistrand, insulated hook-up wire; 1mm solder terminal pins, 26 off; nuts and bolts; solder, etc.

Inductors

- 1 18mH, Toko 10RB (L1)
- 1 12mH, Toko 10RB (L2)
- 1 330mH, Toko 10RBH (L3)
- 1 27mH, Toko 10RB (L4)
- 1 22mH, Toko 10RB (L5)
- 1 1mH RF choke (L6)
- 1 4.7mH RF choke (L7)
- 1 100 μ H RF choke – see text (L8)
- 1 FT50-43 toroid ring-core for L8 – see text

Semiconductors

- 1 1N4001 50V 1A rect. diode (D1)
- 1 5mm red LED (D2)
- 1 5mm yellow LED (D3)

- 1 5mm green LED (D4)
- 1 NE5534N op amp – see text (IC1)
- 1 TDA2003V power amp (IC2)
- 1 7809 +9V 1A voltage regulator (IC3)
- 1 7806 +6V 1A voltage regulator (IC4)

Capacitors

- 1 15nF polyester (C7)
- 1 22nF polyester (C14)
- 2 33nF polyester (C9, C22)
- 3 68nF polyester (C6, C10, C16)
- 6 100n ceramic disc, 5mm pitch (C4, C21, C25, C26, C28, C29)
- 2 100n polyester (C8, C24)
- 2 150nF polyester (C13, C17)
- 1 220nF polyester (C15)
- 2 470nF polyester (C11, C12)
- 1 2.2 μ F radial elect. 16V (C5)
- 3 10 μ F radial elect. 16V (C1, C2, C18)
- 2 100 μ F radial elect. 16V (C3, C27)
- 2 470 μ F radial elect. 16V (C19, C23)
- 1 1000 μ F radial elect. 16V (C20)

Resistors (0.25W 5% carbon or better)

- 1 1 Ω (R12)
- 2 680 Ω (R6, R16)
- 1 22 Ω (R11)
- 4 1k Ω (R1 to R3, R15)
- 1 39 Ω (R13)
- 2 1.2k Ω (R8, R9)
- 2 220 Ω (R10, R14)
- 1 10k Ω (R4)
- 1 390 Ω (R17)
- 1 100k Ω (see text) (R5)
- 1 560 Ω (R7)

Potentiometers

- 2 10k Ω panel mounting, log (VR1, VR2)

CW Audio Filters – Fig.5

- (Alternative values – see text)
- 2 330mH inductors, Toko 10RBH (L1, L2)
- 1 15nF polyester capacitor (C7)
- 1 33nF polyester capacitor (C9)
- 3 330nF polyester capacitor (C6, C8, C10)
- 1 820 Ω resistor, 0.25W 5% carbon or better (R6)

Note: resistor R8 is not used – see text

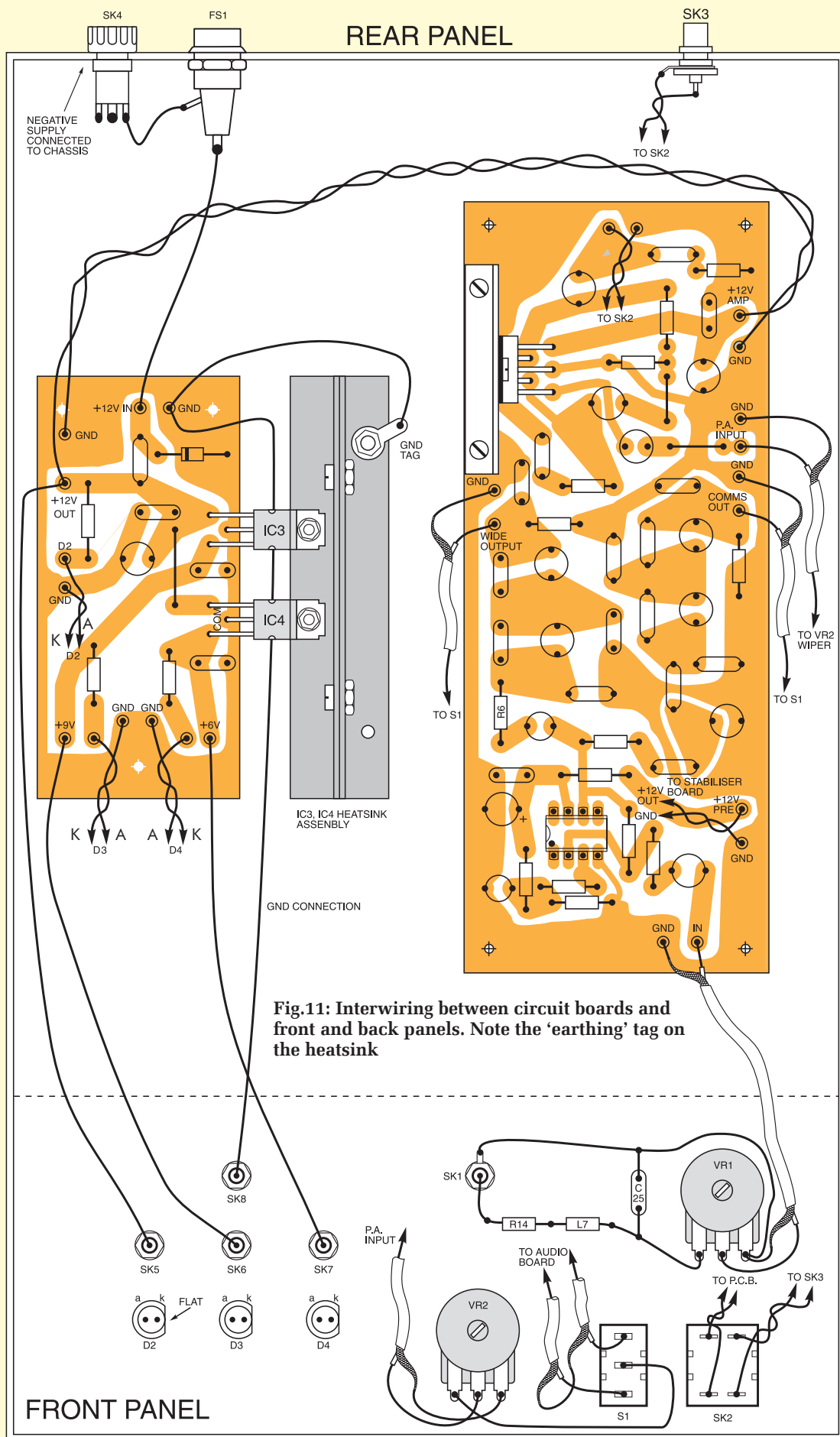


Fig.11: Interwiring between circuit boards and front and back panels. Note the 'earthing' tag on the heatsink

was that all the current consumed by the circuits in the unit, and the external current supplied via the +12V, +9V and +6V outputs, flows through this choke and there was concern that the resistance of a typical off-the-shelf inductor (typically 10Ω) would drop too much voltage and waste power.

Winding L8 is very straightforward. Simply cut a 30cm length of 0.56mm (24 s.w.g. or similar) enamelled copper wire and wind about 14 turns on an FT50-43 toroidal core. This will give the 100μH inductance needed with a very low series resistance. Trim the ends of the winding, scrape off the enamel insulation, tin the leads and solder onto the PSU board.

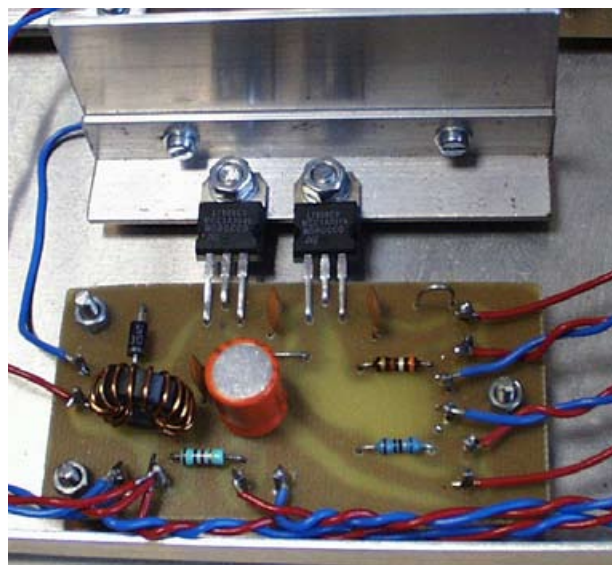
Enclosure

The whole assembly is housed in a two-piece screened aluminium case, size 200mm × 150mm × 75mm. The general arrangement in the case of the boards and chassis-mounted components is shown in Fig.11

The front panel has been shown 'bent down' so that the wiring to its components can be seen. Screened audio cable should be used for the audio connections.

Drilling requirements for the front and rear panels can be seen in the photographs. Make sure you have all the dimensions for panel-mounted components before you start drilling.

In the prototype, the socket used for SK4 did not have a tag connected to the negative outer of the supply's plug. This negative outer was connected directly to the metal case of SK4, and is therefore automatically connected to the metal case of the unit.



The author used a speaker like the ones supplied with PCs, which typically have a phono plug fitted to the audio lead. Alternatively, a separate speaker could be fitted to the lid of the unit if desired.

Setting up and checking

Thoroughly check the locations and polarity of the components on the two boards and check that all the solder joints are good, with no solder bridges or shorts on their underside copper tracks. Double-check the inter-board wiring, especially the power wiring.

Before plugging in the external power supply, check that it is set to +12V DC and that the same +12V is present on the inner part of the plug that will be plugged into SK4.

Now plug in the external 12V supply and check that LED D2 lights and that the +12V output on SK5 is also at +12V. If this voltage is correct but the LED does not light, check that you have wired it the correct way round. Similarly, check the voltages at sockets SK6 and SK7, and that their LEDs D3 and D4, also light. If the voltages at SK6 and SK7 are not correct (within a few millivolts), switch off and re-check the wiring. Because the two regulators are fixed-voltage, no setting up or trimming is required.

If you have an audio signal generator available, set it for a sine wave at about 1kHz and 1V peak-to-peak and connect it to socket SK1. Connect a loudspeaker to SK3 or phones to SK2. Adjusting potentiometers VR1 and VR2 should adjust the output volume level.

Check that the wiring to SK2 is correct by ensuring that audio to a loudspeaker plugged into SK3 is disconnected when headphones are plugged in.

The frequency response of the two filters can be roughly checked by varying the frequency of the signal generator in the two positions of switch S1. The communications filter should start to strongly attenuate the audio above about 3kHz and the wideband filter above about 6kHz.

If an audio signal generator is not available, connect the unit to an audio source, maybe the Record or



Tape output of a receiver and make sure VR1, VR2 and S1 behave as expected.

In use

With the prototype, a 1.2A-rated 12V power supply was used, although the unit itself certainly does not consume this amount of current.

The unit is very simple to use. If you have an external circuit that needs power, simply feed it with the required power from SK5, SK6 or SK7 as appropriate, and connect its common (0V) side to SK8. If there is no short-circuit in the external circuit, then the appropriate LED will remain lit.

Connect the audio output from the external circuit to SK1 and adjust VR1 and VR2 until you can hear a comfortable audio level from the external speaker or phones. Adjustment of VR1 and VR2 is somewhat iterative to get the correct settings. VR1 is intended to be set at a level that prevents overloading of the preamp stage, whereas VR2 sets the volume level from the unit.

Typically, the wide bandwidth setting via switch S1 is used when listening to broadcast stations, whereas the comms bandwidth is used for listening to SSB (single sideband) and CW signals in the amateur bands. Of course, if the CW audio filter has been included, this should only be used for listening to CW transmissions, and is not wide enough for listening to voice transmissions.

Finally

The audio board can be incorporated into a new receiver you might be working on. In this case, VR1 would not be fitted and the overall gain of the op amp stage would be set by adjusting the ratio of resistors R3 and R5. **EPE**

PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

AT ONE time the world of electronics was dependent on high voltages, and circuits would not work properly without them. A low voltage circuit was one that used special valves and required a supply potential of about 30 to 45 volts! This changed when semiconductors replaced valves, with many of the 'new' components perishing if they were even briefly subjected to more than a few volts. Later semiconductors were a little hardier, but apart from a few special devices intended for use in television receivers, they could only withstand quite modest potentials.

The situation is not really much different with modern semiconductors, and it is probably worse in the case of integrated circuits. Many of these devices are intended to operate at supply potentials of a few volts, and can be damaged by anything more. In the normal course of events this is unlikely to be of any practical consequence. The circuit designer knows the requirements and limitations of the components he or she uses, and the circuit is designed accordingly. On the face of it, nothing can go wrong.

Potential problems

A major problem with modern semiconductors is not a likelihood of failure when they are connected into a circuit, but is more one of them being zapped before they reach the circuit! There are voltages present in a normal environment, some of which are surprisingly high. Most of the time there is no obvious sign of these voltages, and you are left unaware of their presence. They only become apparent when of sufficient magnitude to make your hair stand on end, produce a spark each time you stroke the cat, or something of this nature.

Some semiconductors tend to be regarded as safe from static charges, while others are regarded as highly vulnerable. Apparently, this is not a strictly accurate way of viewing the matter, and most semiconductor manufacturers now warn against getting any semiconductor components close to large static charges. Semiconductors are mostly quite tolerant of brief bursts of high current, and will often survive substantial overloads provided they are brief and no overheating occurs.

The situation is different with voltages, where even brief overloads tend to cause damage that often leaves components in

an unusable state. It does not really make much difference whether the source of the voltage is a static charge or a normal power source such as a battery. In either case, it is likely that even a very short exposure to a suitably high potential will result in damage to a semiconductor component.

Consequently, it is essential to keep any semiconductor components away from possible sources of large static charges. You are probably all too aware of any prolific generators of static electricity in your home, such as television sets, computer monitors, carpets, and pets. Components are most vulnerable when they are loose, but damage is still possible when they have been fitted onto a circuit board. A board should be safe once it has been housed in a case, but the semiconductors it contains have to be regarded as slightly vulnerable until it has been properly installed in some form of housing.

Big build-up

While practically all semiconductor devices are to some extent vulnerable to static charges, some are in far more danger than others. Components such as discrete transistors, rectifiers, and diodes are not at great risk, and the same is true of some integrated circuits. The components at most risk are those manufactured using some form of MOS (metal oxide semiconductor) technology. This vulnerability is largely due to the ultra-high input impedance of these components.

An input impedance of a million megohms or more is quite normal for a MOS device. Ordinary bipolar transistors have quite low input impedances, which usually results in any static charges being leaked away long before dangerously high potentials are reached. With MOS devices the input impedance is so high that static charges are not leaked away, and are left to build up until the device breaks down. This

removes the static charge, but the device is likely to be destroyed in the process.

Few discrete MOS transistors are used in modern electronic circuits, but this is not to say that MOS technology is not used much these days. In fact, the opposite is true, with many integrated circuits being based on some form of MOS technology. This includes all CMOS logic devices, such as the 4000 series components and the 74HC00/74HCT00 series. There has been increasing use of MOS technology in recent years, and many other digital chips are built using CMOS or some other form of MOS technology. This includes most of the more complex devices, including memory chips and microcontrollers.

It is less common for things such as radio and audio chips, but MOS technology is used for the manufacture of some linear devices. It is used in some operational amplifiers (op amps) for example. The world of digital electronics is not totally dominated by MOS components. The original 7400 series of logic chips are based on ordinary bipolar transistors, as is the popular 74LS00 series. For the beginner it can be difficult to determine which semiconductors require the 'kid gloves' approach, and which are less vulnerable to static charges.

Fortunately, any components at risk should be clearly identified as such in the article, and component catalogues usually point out any devices which can be easily damaged by static charges. This information should always be available from the data sheet. The data sheet for practically any semiconductor component can be found on the Internet by entering the type number and 'data sheet' into a search engine. If in doubt, always assume that a device is one that is vulnerable to static charges.

It is worth pointing out that MOS components can be damaged by relatively small static voltages, and it is not necessary for sparks to fly in order to zap one of these components. With a MOS component it is quite possible to pick it up and accidentally zap it without there being any noticeable signs of trouble. This would result in your new project failing to work, but you would not know why there was a problem.

Having identified the faulty component there would be no way of knowing the cause of its demise. It could have been destroyed by static, but you could not rule out

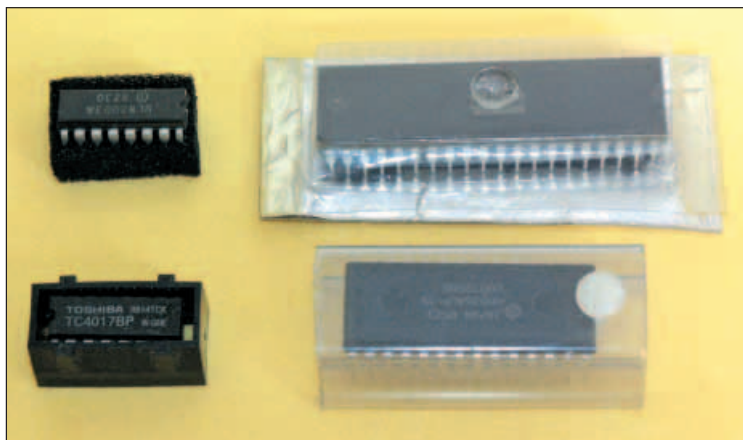


Fig.1. Four types of anti-static packing. Clockwise from top left-hand corner they are: conductive foam, blister pack (with conductive backing), plastic tube, and conductive plastic holder

some other cause such as it being damaged during construction, or it simply being faulty as supplied – although that is much less likely. Voltages of sufficient magnitude to damage MOS devices do not necessarily make their presence felt, but such voltages are often found in everyday environments.

Sent packing

MOS devices should be supplied in some form of anti-static packing, and they are not at risk from static charges while they are in this packaging. An obvious precaution is to leave devices in their anti-static packaging until it is time for them to be fitted to the circuit board. While it is tempting to remove the components from their packing and have a look at them, this is something that should definitely be avoided.

Anti-static packing comes in several different forms, including conductive foam, blister packs, plastic tubes, and conductive plastic bags. Some typical examples of anti-static packing are shown in Fig.1.

Most anti-static packing provides protection by short-circuiting all the pins or leads of the components together, which does not actually keep high voltages at bay. This method works because it is not a high voltage *per se* that causes the damage, but a high voltage between two pins or leads that ‘blows’ some of the semiconductor junctions. With the leads or pins connected together, no significant voltage differences can be produced between them. A different approach is taken with the plastic tubes, which are designed to insulate their contents from static charges.

Keeping components in their protective packaging for as long as possible helps to avoid problems, but obviously at some point it becomes necessary to remove them so that they can be fitted to the circuit board. Semiconductors are sometimes supplied in packaging that has warning notices which suggest that the components have little chance of survival unless they are dealt with using some very expensive anti-static equipment. Fortunately, the reality is rather different, and it is by no means essential to use expensive equipment when dealing with even the most sensitive of components. Some simple precautions are the only practical option for most electronic hobbyists, but these should be perfectly sufficient.

The most obvious precaution is to keep components well away from any obvious sources of static charges. This is something that you should always do anyway, but it is especially important once static-sensitive components have been removed from their anti-static packing.

If there are any known sources of static charges in your home, keep semiconductors well away from them, and do not undertake project construction anywhere near them. At one time most people had at least one or two items of clothing that exhibited a tendency to produce static charges, but these days man-made fibres are normally mixed with natural fibres, and this largely eliminates the problem. However, if you have any clothes that show any signs of producing static charges, do not wear them when dealing with semiconductors.



Fig.2. A conductive wristband connects to the mains earth via a lead that has a high series resistance, and a special (safe) form of mains plug

Sockets

When fitting semiconductors to a circuit board, always avoid touching the pins or leadout wires any more than is absolutely necessary. Unfortunately, it will not usually be possible to avoid touching them altogether. It might be possible if you are equipped with an integrated circuit insertion tool, but even then it is likely that there will be the occasional awkward component that requires some straightening of the pins by hand before they will fit into the circuit board.

It is important that MOS devices are fitted in holders and are not soldered direct to the circuit board. Actually, it is advisable to use holders for all DIL integrated circuits. In addition to avoiding the risk of overheating the components when soldering them in place, it also makes it easy to correct a mistake if one of them is accidentally fitted the wrong way round. Desoldering multi-pin components from a circuit board without damaging anything can be very difficult, even if you have the right tools. By contrast, removing a device from a holder and refitting it correctly is pretty straightforward.

Do not fit the integrated circuits into place until the circuit board and all the wiring has been completed. Holders are less important for discrete transistors and are little used in practice. Where semiconductors are fitted direct to the circuit board they should be the last components to be soldered into place. And the soldering iron used should have an earthed bit.

Down to earth

When dealing with inexpensive components, it is probably not worthwhile going beyond the simple procedures outlined previously. When dealing with more expensive devices it might be prudent to take further measures, and there is plenty of equipment available that can help to keep static charges at bay.

The main problem with most of this equipment is that it is not particularly cheap, and it is not a realistic option for most amateur users. Upmarket equipment that is well worthwhile for professionals dealing with thousands of pounds-worth of components is probably not going to be

viable for a typical amateur user. The equipment is likely to cost more than the total value of the components it will be used to protect, while providing only a slight reduction in the risk of damage occurring.

It might be worthwhile investing in some of the lower cost anti-static equipment if you are likely to use a lot of relatively expensive semiconductors. An earthing wristband probably represents the most cost effective item of anti-static equipment. A device of this type comprises of three pieces, which are the wristband itself, an earthing plug, and a lead to connect the two (Fig.2). Its purpose is to earth the user to the mains earth so that static charges leak away to earth instead of building up in their body.

If the earth lead should become ‘live’ it would be difficult for someone to remove the wristband, so for safety reasons the

earthing lead includes a high value series resistor. The series resistor has a value of several megohms so that the current flow would be far too low to cause any injury if anything should go seriously wrong. The currents involved with static charges tend to be quite small, so the resistors do not prevent any charges from rapidly leaking to earth.

While it is possible to improvise earthing equipment of this type, it is best to either buy the genuine article or not bother at all. Improvising something that protects the components but leaves the user at risk is definitely not a sensible way of going about things, and the cost of a proper anti-static wristband is not particularly high.

The best low-cost alternative to using a proper wristband is to periodically touch something that is earthed, which should remove any charge from your body well before dangerous voltages can build up.

Practically any item of mains powered equipment that has an earthed metal chassis should make a good earthing point. Workshop power supplies, oscilloscopes, and PCs are suitable, but you must touch bare metal such as a fixing screw and not paintwork or plastic coatings. The equipment must be plugged into the mains supply in order to provide a proper earthing point, but it does not have to be switched on.

Mat finish

Taking things a stage further, an earthing mat can be used on the workbench. This is a mat made from a conductive material that is earthed in the same way as an earthing wristband. Its presence more or less guarantees that there can be no build-up of static charges in the user’s body, the components and tools on the mat, or anything within the vicinity of the mat.

It is possible to improvise something if a ready-made earthing mat is deemed too expensive. A piece of aluminium foil glued to a thin sheet of plywood or MDF provides a cheap but reasonably durable conductive mat. It can be earthed via a plug and lead of the type sold for use with anti-static wristbands. Over a period of time the foil surface might become damaged and have to be replaced, but the cost of doing this should be minimal.



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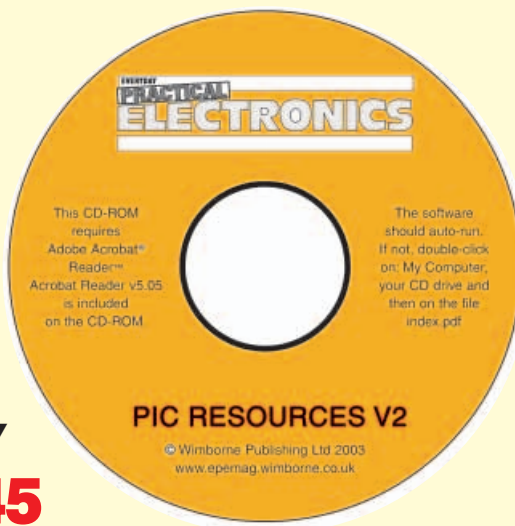
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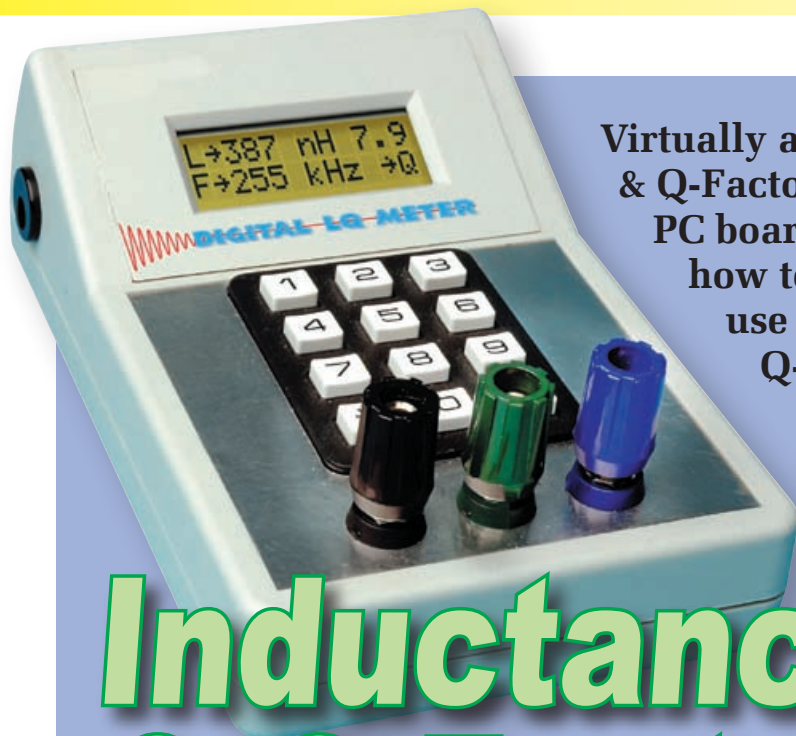
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Virtually all the parts for the Inductance & Q-Factor Meter are mounted on a single PC board, so building it is easy. Here's how to assemble it, check it out and use it to make inductance and Q-factor measurements.

Inductance & Q-Factor Meter

Pt.2: By LEONID LERNER

BUILDING THE INDUCTANCE & Q-Factor Meter is quite straightforward. Fig.9 shows the parts layout on the single PC board.

Begin construction by installing the wire links. All of the links except one can be formed from 0.7mm tinned copper wire or similar. The link situated to the right of Q1 must be fashioned from light-gauge *insulated* wire.

Follow up with the resistors and then continue with all remaining components in order of height. Note that the high-profile components must be mounted as far down on the PC board surface as possible, so as not to interfere with the keypad and LCD when they are installed in the case later.

In fact, the tip of REG3's metal tab had to be removed on the prototype, to clear the rear of the keypad. This can be done using a hacksaw (with the device held in plastic vice jaws) and then carefully filing the job to a smooth finish. Alternatively, you may be able to bend the regulator to achieve sufficient clearance.

When installing the IC sockets, be sure to align the notched (pin 1) ends as indicated in the overlay diagram. Also, check that you have the banded (cathode) ends of the diodes (D1-D8) and the positive leads of the four polarised capacitors the right way round.

The keypad and LCD are connected via lengths of 7-way and a 10-way ribbon cable respectively. On the prototype, an 8-way header is used at the keypad end, while two 6-way headers are soldered to the first six and last six contacts of the LCD module.

We've not included these headers in the parts list because there are several ways the keypad and LCD ends of the cable can be terminated, as well as several types of LCD modules with varying pinouts. You could even solder the ribbon cables directly to the PC boards, leaving out the connectors.

Trial fit the assembly in the enclosure first to gauge the required ribbon cable lengths. Wire up in accordance with the circuit diagram (Fig.5, last month), noting that the pins of the LCD and keypad will not be in the

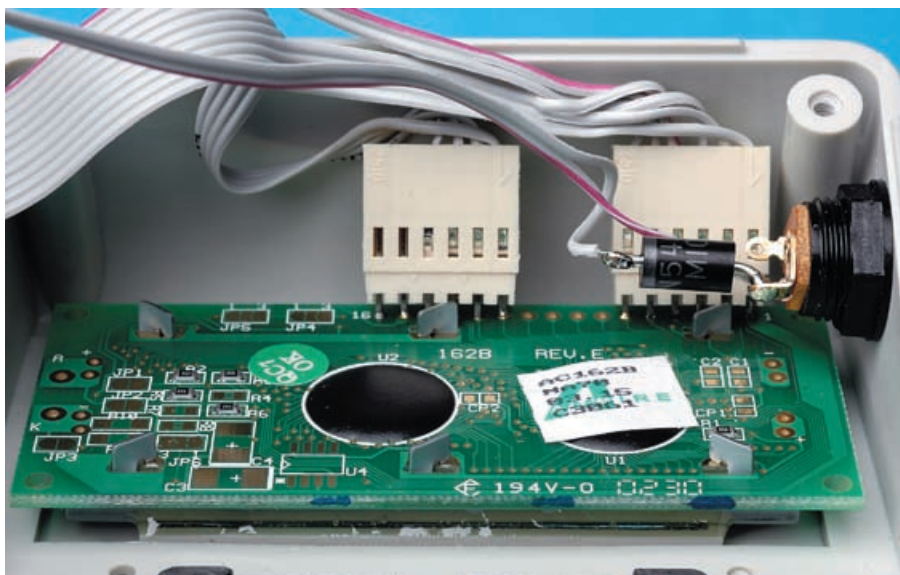
same order as the wires on the ribbon cable.

Finally, in preparation for testing, temporarily fit the three binding posts directly to the PC board in the large holes marked 'A', 'B' and 'E' on the overlay. The posts must be removed after testing and installed in the top of the case as described later.

Basic checks and programming

The unit requires a 7.5V to 9V DC, 200mA power supply. Care needs to be taken here as some 9V DC plugpacks supply much higher voltages when lightly loaded. This extra voltage translates to power dissipation in the 7805 regulator, which may cause it to over-heat and shut down. If you're using an unregulated plugpack, with selectable output voltages, you may find that the 6 or 7.5V setting is sufficient.

As the first step, apply power and check that the +5V and -5V supplies are present on pins 7 and 4 of the AD8055 (IC4) respectively. Also, check for -1.8V on pin 2. Next, adjust the potentiometer (VR1) for optimum



Above: the LCD is glued in place behind the display window and is connected to the PC board via ribbon cable – see text. Note that the diode shown connected to the DC socket here is on the PC board in the final version (D9 in Fig.9).

value. For example, if you've chosen an 8.2nF capacitor, press '8' and then '2'. The display will show '8.2' followed by '100pF', which is the default multiplier. Pressing any key except '*', has the effect of rotating the choice between the 100pF, 1nF, 10nF, and 100nF multipliers. As we're using an 8.2nF capacitor in this example, press any key once to select the 1nF multiplier.

Table 1: Capacitor Codes

Value	μ F Code	EIA Code	IEC Code
100nF	0.1 μ F	104	100n
82nF	0.082 μ F	823	82n
8.2nF	0.0082 μ F	822	8n2
4.7nF	0.0047 μ F	472	4n7
1nF	0.001 μ F	102	1n
820pF	NA	820	820p
680pF	NA	680	680p

Press '*', once you're satisfied with the two parameters. If you make a mistake, pressing '*', at any stage lets you enter a choice or abort a measurement. The display should now show the inductance, Q factor and test frequency.

To make measurements using the internal capacitor bank, insert a link between the 'A' and 'B' terminals. Repeat the procedure above, but note that only choices of 1.0 x (1nF or 10nF or 100nF) make sense here, since only these values are present internally.

The Accuracy of Q readings using the internal capacitors are degraded by the 0.5 Ω (approx.) dynamic series resistance of the transistors, which do the bank switching. This mode is to be used if you're not interested in Q and just want to make inductance measurements.

After the range is chosen, the micro starts sampling at the maximum rate. The first few acquisitions are used to optimise the sampling rate and set a sampling delay if required. The latter occurs when the ringing saturates the input amplifier in the immediate aftermath of the pulse.

After a valid sample is acquired, the micro performs an FFT and the centre frequency is estimated. During a period of eight cycles, centre frequency and bandwidth measurements are performed and the average taken. Finally, the inductance, Q factor and centre frequency are calculated and displayed on the LCD. A complete acquisition, averaging and display period takes about 0.1s for the 10MHz micro.

You may find that the large binding posts are useless when testing physically small inductors. This is easily addressed by making up two short leads to plug into the binding posts. Each lead consists of an uninsulated crocodile clip soldered to a 4mm banana plug via a very short length of large diameter single-strand copper wire or similar.

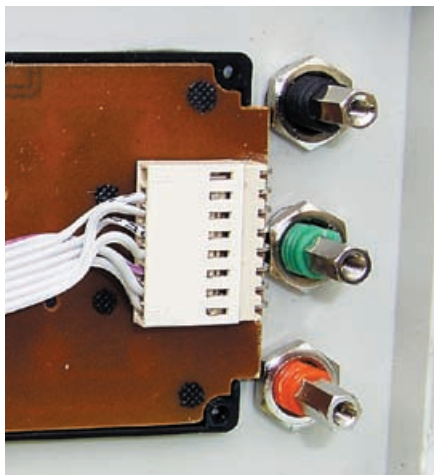
Housing

The completed meter will fit neatly into a console-style instrument case. This should be done after it has been tested and found to be operating correctly, as the keypad and LCD are glued in place and will be difficult to remove later.

An opening for the keypad must be cut out and holes for the DC socket and binding posts should be drilled as shown in the various photographs. Note that the binding post holes must be positioned accurately, otherwise it will be impossible to assemble the unit later. This can be achieved by using the PC board as a template when marking out the holes.

Table 2: Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
□	1	10k Ω	brown black orange brown	brown black black red brown
□	10	4.7k Ω	yellow violet red brown	yellow violet black brown brown
□	2	1.2k Ω	brown red red brown	brown red black brown brown
□	3	1k Ω	brown black red brown	brown black black brown brown
□	1	130 Ω	brown orange brown brown	brown orange black black brown
□	1	120 Ω	brown red brown brown	brown red black black brown
□	8	100 Ω	brown black brown brown	brown black black black brown
□	1	82 Ω	grey red black brown	grey red black gold brown
□	1	56 Ω	green blue black brown	green blue black gold brown
□	2	47 Ω	yellow violet black brown	yellow violet black gold brown



This close-up view shows how the three 10mm tapped spacers are fitted to the binding posts (after first snipping off the non-threaded tips). The PC board is secured to these spacers using M3 x 6mm screws and star washers (see text).

To give the finished unit a professional appearance, a faceplate can be cut from thin aluminium sheeting and fitted around the keypad. The easiest way to achieve this is to lightly mark out the contour of the keypad on the aluminium sheet using a scribe or needle and then drill four 8.5mm holes at the corners.

Next, use a straight edge and Stanley knife to score the sheet front and back, joining the four holes at their perimeters. Cut away the centre of the piece to be removed, then place the sheet in a vice and bend along the scored marks.

Work the metal back and forth at the bend and it will break off, leaving a clean edge.

The LCD, keypad and faceplate can then be glued to the case using two-part epoxy adhesive. To achieve

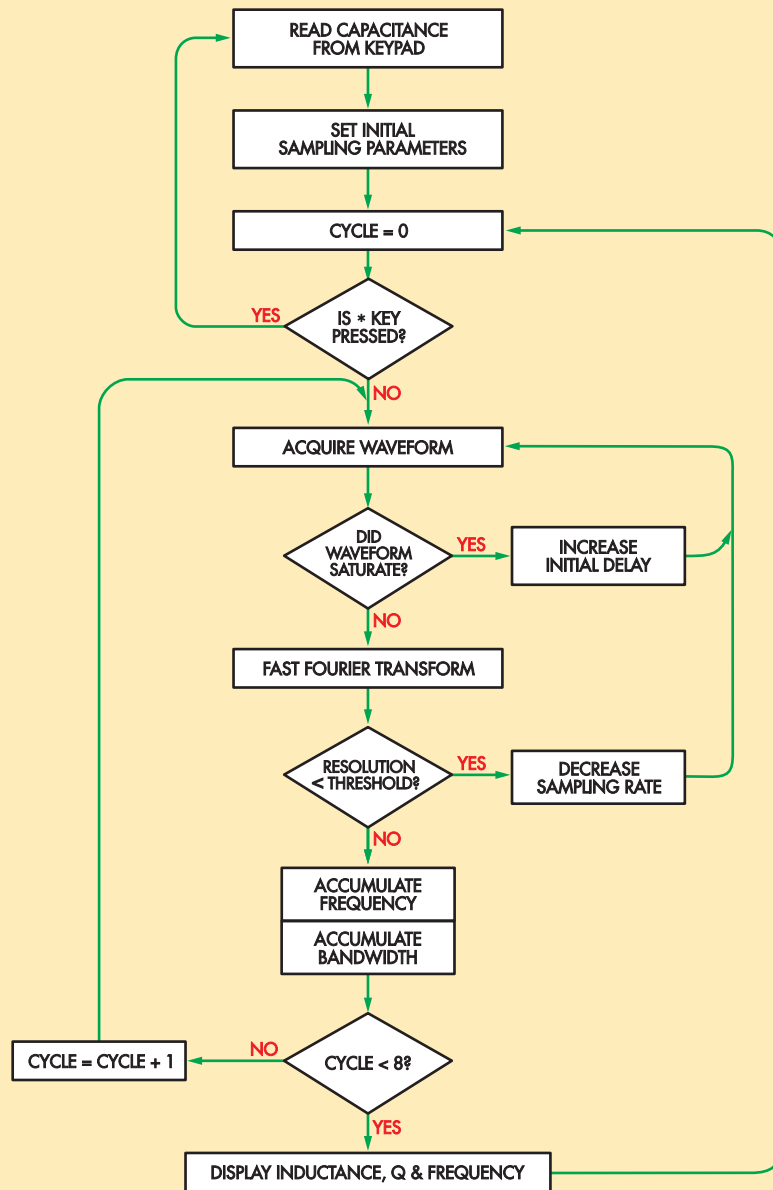
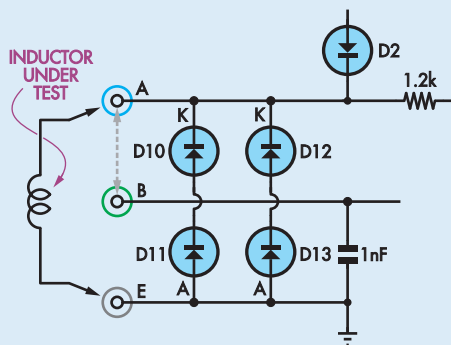


Fig.10: this diagram gives a very basic idea of how the microcontroller program works.

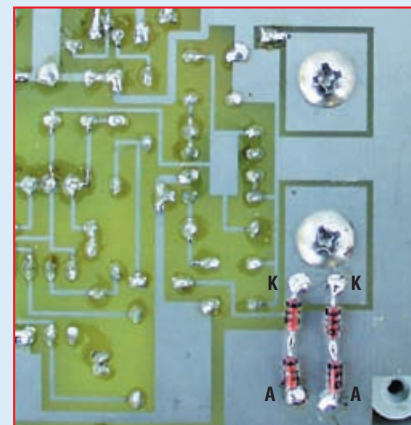
Update: improving the performance

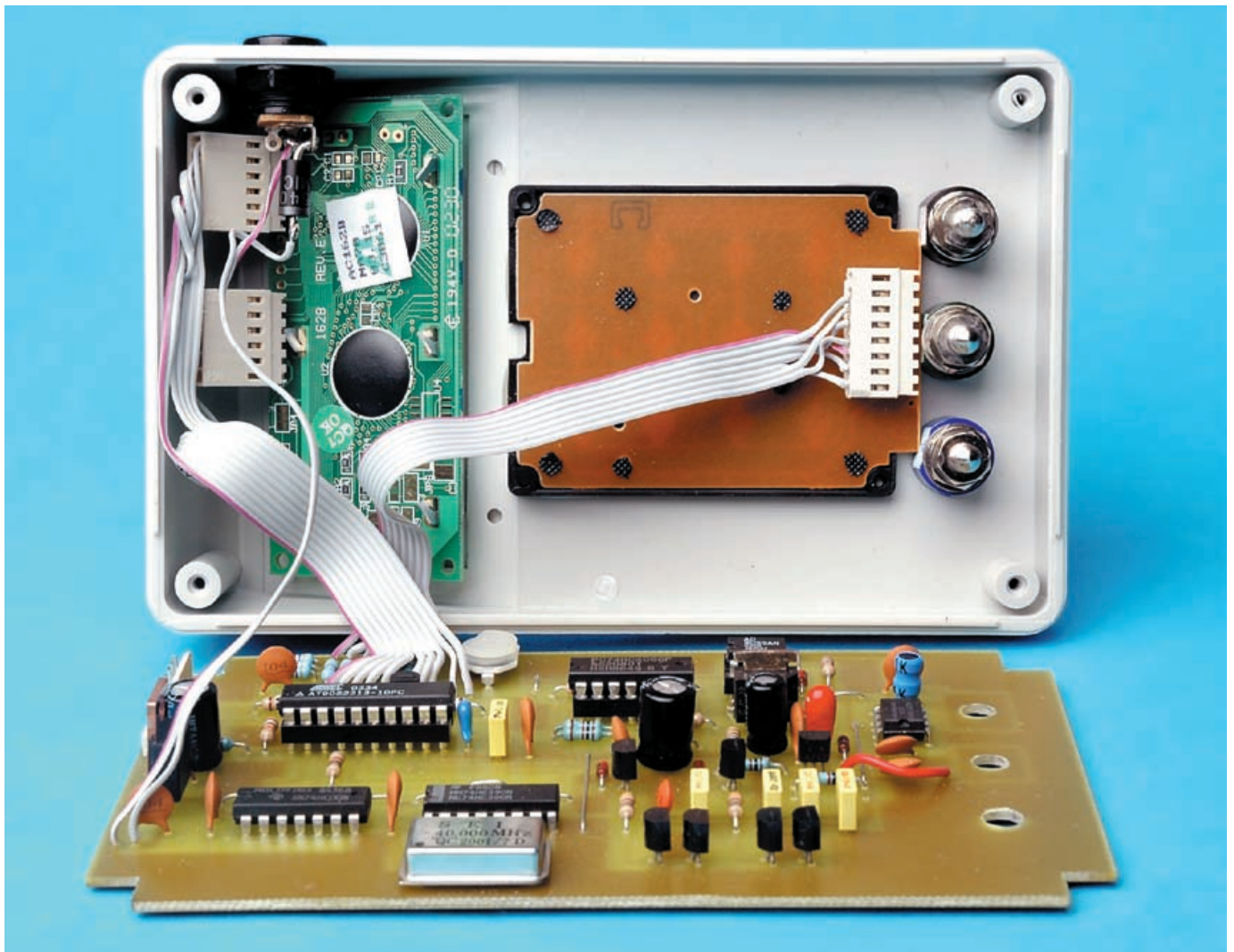
To improve meter performance when measuring certain combinations of L and Q, install two pairs of series diodes (D10-D13) in parallel with the test terminals, as shown in the diagram at right. The diodes can be fitted on the copper side of the PC board (see photo) and must be 1N4148 small-signal types.

These diodes act as dampers, serving to lower the peak of the



ringing waveform to below 1.2V as quickly as possible.





Another view inside the completed prototype. The keypad and LCD are secured to the case using epoxy adhesive.

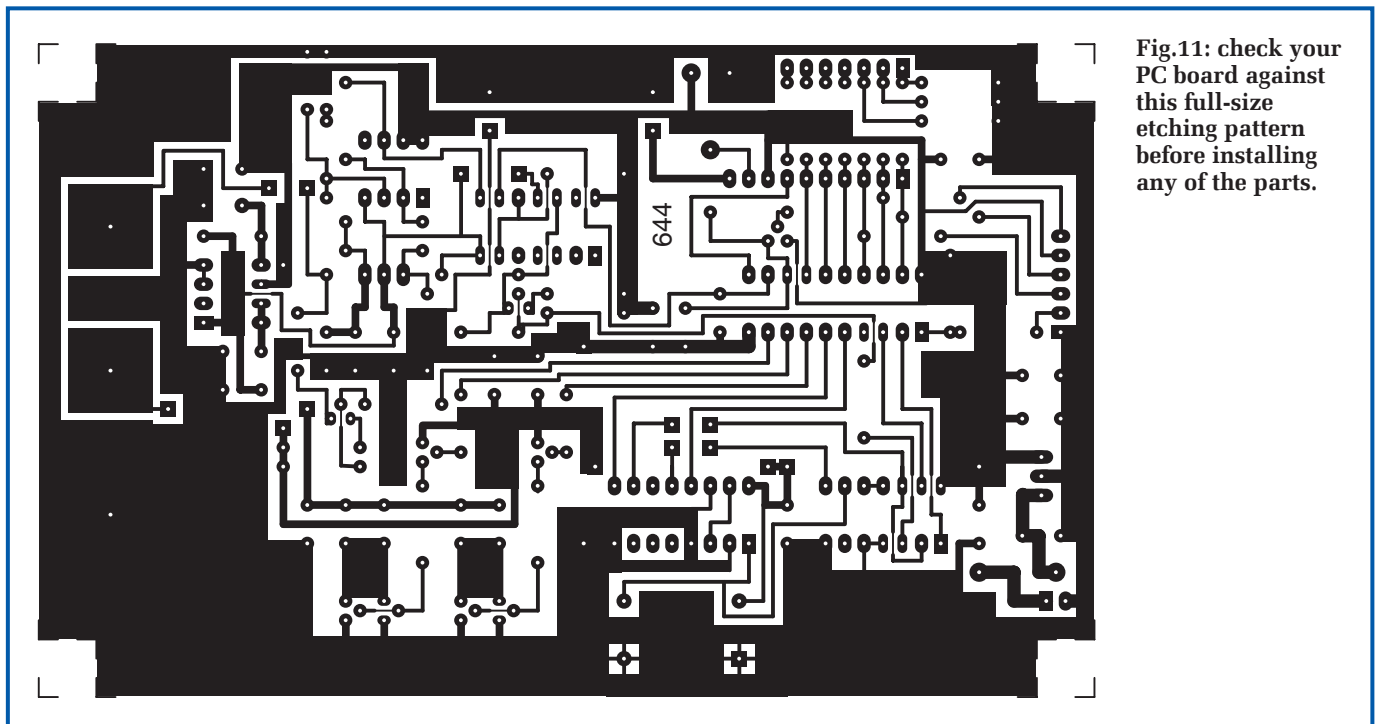


Fig.11: check your PC board against this full-size etching pattern before installing any of the parts.

Parts List – Inductance & Q-Factor Meter

- 1 PC board, code 644, available from the *EPE PCB Service*, size 139.7mm x 86.4mm
- 1 150 μ H miniature ferrite choke (L1)
- 1 black 4mm binding post
- 1 blue 4mm binding post
- 1 green 4mm binding post
- 1 6-way 2.54mm pitch header (for ISP connection)
- 1 2.1mm or 2.5mm panel-mount DC socket
- 1 20-pin IC socket
- 1 16-pin IC socket
- 2 14-pin IC sockets
- 2 8-pin IC sockets
- 1 16-character x 2-line LCD module
- 1 numeric keypad
- 1 console style plastic case, size 150 x 95 x 28.5/49.5mm
- 1 ribbon cable (see text)
- 1 miniature 10k Ω trimpot (VR1)
- 3 M3 x 10mm tapped metal spacers
- 3 M3 x 6mm screws and star washers

Semiconductors

- 1 AT90S2313-10 microcontroller (IC5), programmed with LQ-Meter128.HEX and LQ-Meter128.EEP
- 1 74HC00 quad NAND gate (IC1)
- 1 74HC390 dual decade counter (IC2)
- 1 74HC4066 quad analogue switch (IC3)

- 1 AD8055AN high-speed op amp (IC4)
- 1 MAX635ACPA switching regulator (IC6)
- 2 2N4250 or PN4250 PNP transistors (Q1, Q2)
- 6 2N2222A or PN2222A NPN transistors (Q3-Q8)
- 1 40MHz crystal oscillator module (OSC1)
- 1 LM334Z adjustable current source (REG1)
- 1 7805 +5V regulator (REG2)
- 1 LM337 adjustable negative voltage regulator (REG3)
- 1 1N60 germanium diode (D1)
- 7 1N4148 signal diodes (D2-D8)
- 1 1N4004 rectifier diode (D9)

Capacitors

- 2 470 μ F 16V PC electrolytic
- 1 220 μ F 10V PC electrolytic
- 1 47 μ F 6.3V tag tantalum
- 11 100nF 50V monolithic
- 1 82nF 50V MKT polyester
- 2 8.2nF 50V MKT polyester
- 1 4.7nF 50V MKT polyester
- 1 1nF 50V MKT polyester
- 1 820pF 50V ceramic disc
- 1 680pF 50V ceramic disc

Resistors (0.25W 1%)

- | | |
|------------------|----------------|
| 1 10k Ω | 1 120 Ω |
| 10 4.7k Ω | 8 100 Ω |
| 2 1.2k Ω | 1 82 Ω |
| 3 1k Ω | 1 56 Ω |
| 1 130 Ω | 2 47 Ω |

a good bond to this plastic, the mating surfaces should first be sanded to a rough finish. Make sure that the LCD is centred left to right when you glue it, otherwise some of the characters will not be visible.

Note that even when centred, the entire display width is not visible through the case cutout. This isn't a problem, as the program uses only 12 of the available 16 characters.

Binding posts

The binding posts are first attached to the case using the supplied nuts and spring washers. Next, snip off the very tip of the binding posts, leaving just the threaded portion. The non-threaded part is not needed and would otherwise obstruct the PC board mounting screws.

Now remove the two small M3 nuts and replace them with M3 x 10mm tapped metal spacers, tightening firmly. The PC board can then be held in place by attaching it to the three spacers using M3 x 6mm screws and star washers. Note that the screws and washers must also make good electrical contact with the copper on the PC board.

If there is a problem attaching the PC board to the spacers on the binding posts, check for interference between the components and the rear of the keypad.

Final word

As well as L and Q measurements, some interesting physical phenomena can be investigated with this meter.

First, wind a small choke with a few turns of enamelled copper wire around a Philips screwdriver and check its inductance and Q factor with the meter.

Next, insert a small HF ferrite bead into the coil and observe that the inductance and Q factor increases, as expected. Now replace the bead with the blade of the screwdriver and observe that the inductance hardly changes and may even decrease, while the Q drops markedly.

Ordinary iron is not a useful core material at RF. This is because its magnetic domains cannot keep pace with the fast changing RF field. Rather they vibrate ineffectively and generate heat, introducing nothing but losses into the tuned circuit.

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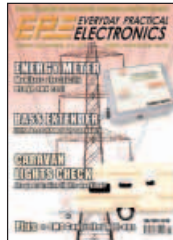
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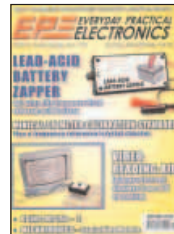
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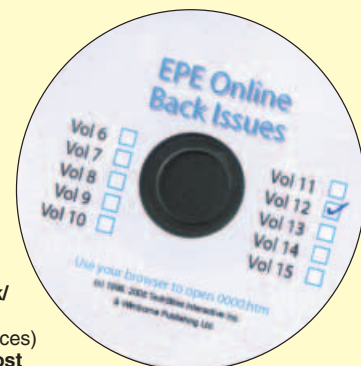
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SMS Controller and Flowcode

Dear EPE,

I read the response in *Readout* of August '07 regarding visualizing coding at a high level and the use of *Flowcode* and thought my recent experience may be of some interest.

I built the *SMS Controller* in the March and April '07 issues and had some difficulty once it was up and running. I used the less preferred Nokia 3210 and found that the phone would randomly switch off, after which I would have to manually switch the phone back on, or occasionally a send error would occur, after which I would need to reset the controller by removing power.

Murphy's law dictated that this would happen when I was not around to reset the device but either way it meant that I would not always receive SMS alerts. I assumed that the phone was in good order as it did not switch off when

not connected to the SMS controller, but I needed a solution to solve this problem.

I built a circuit using a PIC which monitored two of the pins connected to the relevant LEDs on the ATMEL chip in the controller. I took a risk in opening the phone and soldering two wires to the on/off switch which I connected to the switching contacts of a small relay. I also connected a transistor to the Reset pin on the controller's ATMEL chip.

When the problems mentioned earlier occurred, the PIC either switched the phone back on or reset the controller circuit. Although I never did find the cause of the problem, the controller is now happily sending me SMS thanks to my modification.

The reader referred to in the August '07 issue mentioned that *Flowcode* does not explain how to do the Global structure of the program. I used it to program the PIC in my circuit and

some advice that I can offer using *Flowcode* is to set up switch inputs and output LEDs first, then program some simple tasks and run a simulation before getting too bogged down in the more complicated actions.

I believe that it is always beneficial to see code written by others but I have only ever found one other *Flowcode* file on the internet as it seems not to be widely used just yet. If any readers are aware of any sites that share *Flowcode* projects, other than the Matrixmultimedia site, these would be welcomed.

I would also be interested to know if any other readers experienced similar problems with the SMS controller circuit.

Thanks for an interesting magazine.

James Cells,
via email

Thanks for that James. Readers, any comments?

SMD Board Repair

Dear EPE,

In response to the inquiry in *Readout* Aug '07 by Edward Chase regarding SMD board rework/repair, I have the following information he may find helpful.

Having been involved in the teaching of soldering/desoldering techniques on through-hole and SMD devices for several years now, it's important to understand that there are several different ways of removing SMD components, and that some devices, such as ball-grid arrays (BGAs), which are the types of chip where you cannot see the connecting pins, require very specialised equipment using focused hot air or infra-red heat.

Gull-wing, J-leaded and chip components can be easily removed using a special low-melting point alloy supplied by Chip Quick. The following link gives details of the product and an example of how to use it: www.chipquik.com/store/prod_template.htm.

Replacing SMD devices is pretty straightforward and it's advisable to use magnification equipment to align the component with the pad. The following link has some tutorials:

www.dynamixtechnology.com/docs/ipc-7711amend1.pdf.

Tom Connelly
(Lecturer in Electronic Engineering,
Cardonald College, Glasgow.),
via email

Lead Acid Battery Zapper

Dear EPE,

On studying the *Lead Acid Battery Zapper* (July '07), I note that the 3A fuse

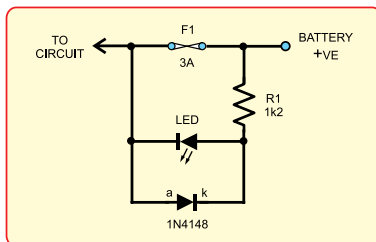


Fig.1. Circuit modification to the Lead Acid Battery Zapper

can blow due to a circuit malfunction ... fair enough. However, as the Zapper is connected across the battery (say, via the cigar lighter), there is no indicator to show a blown fuse condition. One might imagine that all is well and assume the battery is beyond recovery.

A simple circuit across fuse F1 will put things right, see Fig.1. The LED shows if power is reaching the circuit via the fuse (LED off), or if there's a blown fuse (LED on). The 1N4148 signal diode protects the LED in the event of an incorrect battery connection.

P.G. Diestler, Middleton,
Manchester

Thanks for that. A worthwhile amendment it would appear.

Printing Problems

Dear EPE,

Your readers may be interested to know that there is no need to use any additional software to get older DOS-based pro-

grams to print in a Windows environment. I am running Win XP and I have many older EasyPC PCB designs that I easily coax directly to my USB printer. I print straight onto transparencies for use in an exposure box. This is how it is done, taken from <http://geekswithblogs.net/dtetzke/articles/26204.aspx> – I am not taking credit for this – only for telling you!

1. Install a Microsoft Loopback Adapter
 - a. In Control Panel, double-click on Add Hardware
 - b. Click Next
 - c. When the scan finishes, select 'Yes, I have already connected the hardware'
 - d. Click Next
 - e. Scroll to the bottom of the list and select 'Add a new hardware device'
 - f. Click Next
 - g. Select 'Install the hardware that I manually select from a list (Advanced)'
 - h. Click Next
 - i. Select 'Network Adapters'
 - j. Click Next
 - k. Select 'Microsoft' under the Manufacturer list
 - l. Select 'Microsoft Loopback Adapter' in the Network Adapter list
 - m. Click Next
 - n. Click Next
 - o. Click Finish

2. Configure the Adapter
 - a. The loopback adapter is a virtual network adapter and can be configured the same as a regular network card
 - b. Set the adapter to have a static IP address such as 192.168.1.1/255.255.255.0

3. Share the printer
 - a. I recommend you use a share name that you will remember. I used 'Printer' in the new machines that are already deployed
4. Capture the printer port
 - a. NET USE LPT1: \\Computer Name\Printer /PERSISTENT:YES

I stick the last line in a .bat batch file that I run before I load EasyPC in a DOS shell. You can also add it to the startup sequence in Windows.

There you have it. No extra software. It works very well!

EPE's a great mag. I have been reading it for years.

Elemer Nyiry,
via email

Thanks Elemer, that's a very detailed response which I hope will help others.

Techno Talk and Eco Lamps

Dear EPE,

Mark Nelson's *Techno Talk* of July has an error in it. Like all the articles I have read on this topic, the writers forget that most light bulbs are in rooms! When a light bulb is in a room it is part of a system. For most of the year switching on a light makes no difference to the energy input to the room, because the room is heated.

Consider a temperature controlled electrically heated room. When you switch on a 100W light the temperature controller will cause the electric heater to give out 100W less energy to maintain the same temperature (a 100W light bulb produces 100W of heat). The energy supply to a room is constant for a constant room temperature. The illumination is free in this situation. Note that the same logic applies to switching on a TV in a heated room. The energy input to the room does not change, so it costs no more energy to have the TV on.

Switching off a light, or changing to a more efficient one, is only energy saving if one of these statements is true:

- * The light is outdoors
- * The room it is in is unheated
- * The room it is in is heated by a wood fire
- * The room it is in is heated, but not temperature controlled, either by a thermostat, or manually

I hope you find this interesting and helpful.

Alan J. Munday,
Southampton, via email

Mark replies:

Alan has a point that the heating effect of a 100W incandescent lamp bulb is a means towards heating the room but it's not an efficient method of raising the temperature. And in summer you don't want this extra heat.

Mark Nelson,
via email

I would comment that I often turn down a room's temperature control, if lighting etc is making it too warm. It can also be of benefit at times if it's so cold that the central heating does not reach a particular room soon enough, especially the workshop.

Suck or Blow Fans?

Dear EPE,

Many readers will no doubt remember the *Readout* discussions about whether fans should suck or blow. After many years away from the HF bands, I've just bought a transceiver (secondhand). The power amplifier (PA) contains valves, which are more resilient than transistors in this application and I stand some chance of mending it if it goes wrong! But, they do get hot.

Another part of the equipment is a screened enclosure containing the variable frequency oscillator (VFO), the principal frequency-determining section of the whole transceiver. VFOs are invariably temperature sensitive to some extent, but you don't want to be drifting all over the band and interfering with other people's contacts.

The cooling fan is an add-on unit, fortunately present on my example. It draws air directly out from the screened PA compartment, venting to the surrounding atmosphere. If it blew inwards, the airstream would heat up on passing the PA valves and, next, would find its way into the body of the set and gently warm the VFO, causing drift.

Diffuse room-temperature air (hopefully constant temperature in the short term) is pulled into the equipment case and drifts slowly through the large volume containing solid-state circuitry, before picking up speed into the small PA compartment and finally being concentrated into a fast stream that is ejected through the small aperture of the fan. Analogy: a river flows slowly and diffusely at a wide point (or the delta) but speeds up when forced through a narrow culvert, the total current in litres/second being the same in each case.

So, to blow or to suck? Depends on the route that you want the hot air to take after passing over whatever needs to be kept cool.

Godfrey Manning G4GLM,
Edgware, via email

Thank you Godfrey

Historic Equipment

I know we all squirrel away stuff against some future time when we might need it – it seems to be the defining feature of an engineering mind!

Where it gets tricky is a friend's late dad's workshop, which particularly includes electrical/electronic stuff. He apparently was a bit of an inventor – he ran a small engineering business for a while.

Instead of the couple of shelves in the garage that most of us get, this guy had a workshop the size of two average sitting rooms and about 15ft high in which to squirrel stuff – as a result, it's got stuff piled floor to ceiling everywhere. There's *EPEs* and other old magazines going back to the 80s, plus loads of workshop manuals and old databooks, some going back to the 60s. There's old voltmeters, ammeters, ohmmeters, frequency counters, oscilloscopes, etc. There's components varying from brand new to years old.

There's tubes and other old stuff still in their original packaging (my friend says she forgot to show me the 1920s Osram light bulb in its original box). There's PCBs going back years and years. There's old 4-tracks, TVs and radios and record decks. There's various jigs for unknown purposes, some of them with motors attached, or drive-belts and pulleys. All of it is in a completely unknown state of repair.

As much as I'd love to provide a home for this historical archive, there's no way I can do it. I don't even have the time to sort through it properly – there's a phenomenal amount of stuff in there. So does anyone know of any place which would be interested in keeping any of this stuff as historical artifacts, or is there actually anyone here who collects stuff like this, or who would be interested in looking through it to see what they could use?

It seems criminal to throw all this stuff into a skip, but equally, I've no idea what we could do with it. Just working through it all to put it on eBay would take ages, and anyway, the friend doesn't know anything about electronics and I don't have the spare time to do it.

The friend is particularly keen for this stuff to go to people who'd use it or to collectors, rather than to a dealer (if there is such a thing as an historical electronic component dealer). The place is just outside Kettering.

Graham Bartlett ('Grab' on CZ)

Thanks Graham, If any reader is interested, or knows someone else who's might be, drop EPE a line, either by post or email, as on the Readout heading, marked for my attention.

Best SMT Soldering Equipment

Dear EPE,

What would you say would be the best soldering equipment I could purchase for hand soldering SMT products onto prototype boards. I don't necessarily want the cheapest but I don't want to go over the top either. In the past I've used both Antex and Weller irons/stations for standard soldering, but I'm now getting confused with terms like 'rework', 'hot air flow' and many other strange terms associated with SMT/SMD.

Basically what I'm asking is, 'If I want to do prototype work with SMT products what's the best choice of soldering equipment I should purchase to do the job efficiently?'

Glynne Hewlett,
via email

Alan Winstanley's our soldering expert. He replied to Glynne:

Probably the best place to ask would be in our forum at [www.chatzones.co.uk/EPE Chat Zone](http://www.chatzones.co.uk/EPE%20Chat%20Zone), there are plenty of users with practical experience who I'm sure will be happy to help. Also, Antex has a wide variety of fine tips and devices designed for hand-soldering SMDs on their web site, see www.antex.co.uk.

It is possible to spend a fortune on hot-air reworking tools but this could be overkill for all but the most serious work and it might be hard to justify the cost. A reader has previously recommended the Skil heat gun as it's thermostatically controlled, for desoldering and removing SMT chips and has a suitably fine reducer nozzle. Browse:

www.lawson-his.co.uk/scripts/products.php?cat=Heat%20Gun&source=froogle.

Alan Winstanley,
EPE On-Line Editor

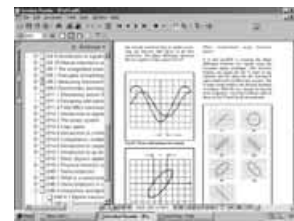
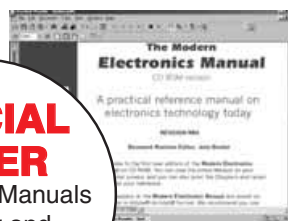
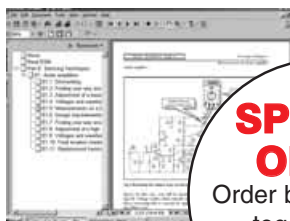
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Net Work

Alan Winstanley

Anti-virus software

This month's *Net Work* discusses some of the current anti-virus and security offerings available to Internet users.

Viruses and 'malware' arrive on a computer in many ways, including via certain websites that drop all sorts of malicious code onto a visitor's machine without their knowledge. I never cease to be amazed by the number of people who run their machines without any form of anti-virus protection. This is very poor and anti-social 'PC hygiene' because not only can it cause valuable data to be lost, but it can also contribute to their machines being hijacked in order to, for example, generate spam or attack other websites with excess traffic.

'Any protection is better than none' and a number of free anti-virus solutions are available that will help protect users online. In previous editions of *Net Work* I suggested the free Avast! anti-virus package (from www.avast.com) for home use. This has been in regular use on the author's home machines and laptops, but it has gradually started to look dated and the time eventually arrived to compare it with some new and more polished rivals. A trial of an alternative product also revealed a number of unwanted viruses residing on a system that the current software had apparently let slip through, so the time for change was ripe.

Some products arrive in fancy retail packaging but many, both free and paid-for, are downloadable for use straight away. So-called 'total Internet security' products have a suite of features that can prove a heavy workload for a modest PC specification, so there is no substitute for testing a program over a period, looking not only at its effectiveness in catching virus-laden emails, files and possibly blocking spyware, but also assessing usability, frequency of updates and ease of use, without slowing down a PC too much. Hence, if a trial mode product is available, eg for 30 days, I strongly recommend readers take advantage of it to see how usable it is.

It is unwise to run two anti-virus products side-by-side and an installer will often detect and un-install existing anti-virus programs first. Therefore, ensure that existing program CDs and serial numbers etc. are available in case you change your mind and re-install them later.

Some of the best known names in anti-virus include Norton Antivirus 2008 which can be purchased in downloadable form for \$39.99 per user per year. Norton 2008 is Vista compatible and it checks for spyware and rootkits as well. See www.symantec.com for details. For users of older Windows machines, legacy versions of Norton 2006 products can be installed on Windows XP/2000/98/Me. Meantime, Norton 360 is an all round Internet security package with a dazzling array of features to protect your privacy and your data. I have not tested this product, but it is compatible with Windows XP and some versions of Vista. More from www.symantec.com/norton360/



McAfee is another established brand and their anti-virus range starts with VirusScan Plus, costing £39.99 (\$80) per user per year. It includes anti-spyware protection, together with firewall enhancements. Further information is online at www.mcafee.com. As with other major packages, no demo download is available.

Anti-virus trials and tribulations

AVG Anti Virus from Grisoft (<http://free.grisoft.com/>) is one of the most popular free packages for consumer use. The free version of this software offers basic levels of protection only with no technical support, and its version 7.5 onwards is said to be Vista compatible. Grisoft also offers a free downloadable Anti Rootkit program that helps detect malware hidden deeply in an operating system.

The author tested another popular paid-for anti-virus package, Kaspersky Anti Virus 7.0. After an intensive 15 hour overnight scan, Kaspersky Anti Virus found no less than 90 trojans. In use, though, the product frequently launched intrusive popups at almost every stage of every operation for no apparent reason (and seemingly unstoppable too). Although it appeared to be very thorough, the constant and obtuse popups interrupted even trivial Windows tasks.

Kaspersky did have a useful Pause control but was found to be incompatible with pre-installed Spyware Doctor (from www.pctools.com). Its complexity and its objectionable 'pig squeal' sound effects meant that it was removed from the system after just a few days. Although there was no doubt about its strengths and effectiveness, its usability was a let-down: download a trial from www.kaspersky.com and try it yourself. At the time of writing it was on offer at \$27.96 per year, usually \$39.95. Incidentally, Kaspersky also offers a free online scanner tool at www.kaspersky.com/virusscanner

The final stop was at the website of F-Secure, which offers a range of effective anti-virus programs and Internet security suites. A free demo download of F-Secure Anti Virus 2007 from www.f-secure.co.uk came as a breath of fresh air compared with, say, the over-complicated and nagging popups of Kaspersky. F-Secure's program detects both viruses and spyware and was

much easier to get along with, though it has fewer options than many other programs. Although there is no Pause control to suspend lengthy scans and it has basic logging facilities only, the program was self-explanatory and ran seamlessly in the background with no annoying popups.

In fact, F-Secure Anti Virus 2007 seemed to be the most discrete anti-virus package without being over-elaborate, but for a subscription-based service the best part is the price: £27.50 (\$55) covering up to three machines per year. By the time you read this, the new 2008 version may be available: check their website for details. For now, F-Secure replaces Avast! as my anti-virus product of choice.



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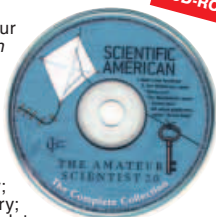
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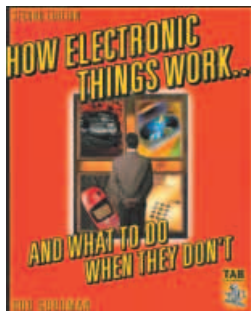
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The fundamental principles of analogue and digital fault finding are described (although, of course, there is no such thing as a "digital fault" – all faults are by nature analogue). This book is written entirely for a fault finder using only the basic fault-finding equipment: a digital multimeter and an oscilloscope. The treatment is non-mathematical (apart from Ohm's law) and all jargon is strictly avoided. 274 pages

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Steve Money

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Brian Hennessy's book also describes the development of broadcasting equipment, the search for premises and looming bankruptcy before ending with the emergence of a firmly established Chartered Corporation – the BBC.

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B. B. Babani

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Owen Bishop

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KEITH BRINDLEY

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R. A. Penfold

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DECEMBER '07 ISSUE ON SALE NOVEMBER 8

ADVERTISERS INDEX

AUDON ELECTRONICS	53
BETA-LAYOUT	53
BRUNNING SOFTWARE	30
BULL GROUP	Cover (ii)
COMPACT CONTROL DESIGN	4
DISPLAY ELECTRONICS	88
ESR ELECTRONIC COMPONENTS	6, Cover (iii)
JAYCAR ELECTRONICS	18/19
JPG ELECTRONICS	88
LABCENTER	Cover (iv)
LASER BUSINESS SYSTEMS	17
LEKTRONIX LTD	57
MAGENTA ELECTRONICS	33
MIKROELEKTRONIKA	5
NURVE NETWORKS LLC	75
PEAK ELECTRONIC DESIGN	33
PICO TECHNOLOGY	27
QUASAR ELECTRONICS	2/3
SCANTOOL	49
SHERWOOD ELECTRONICS	53
STEWART OF READING	45
TECHNOBOTS	11
TSIEN	53

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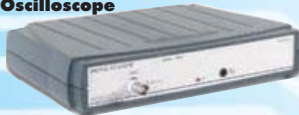
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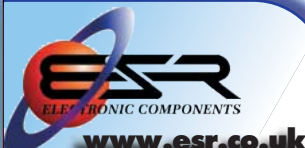
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